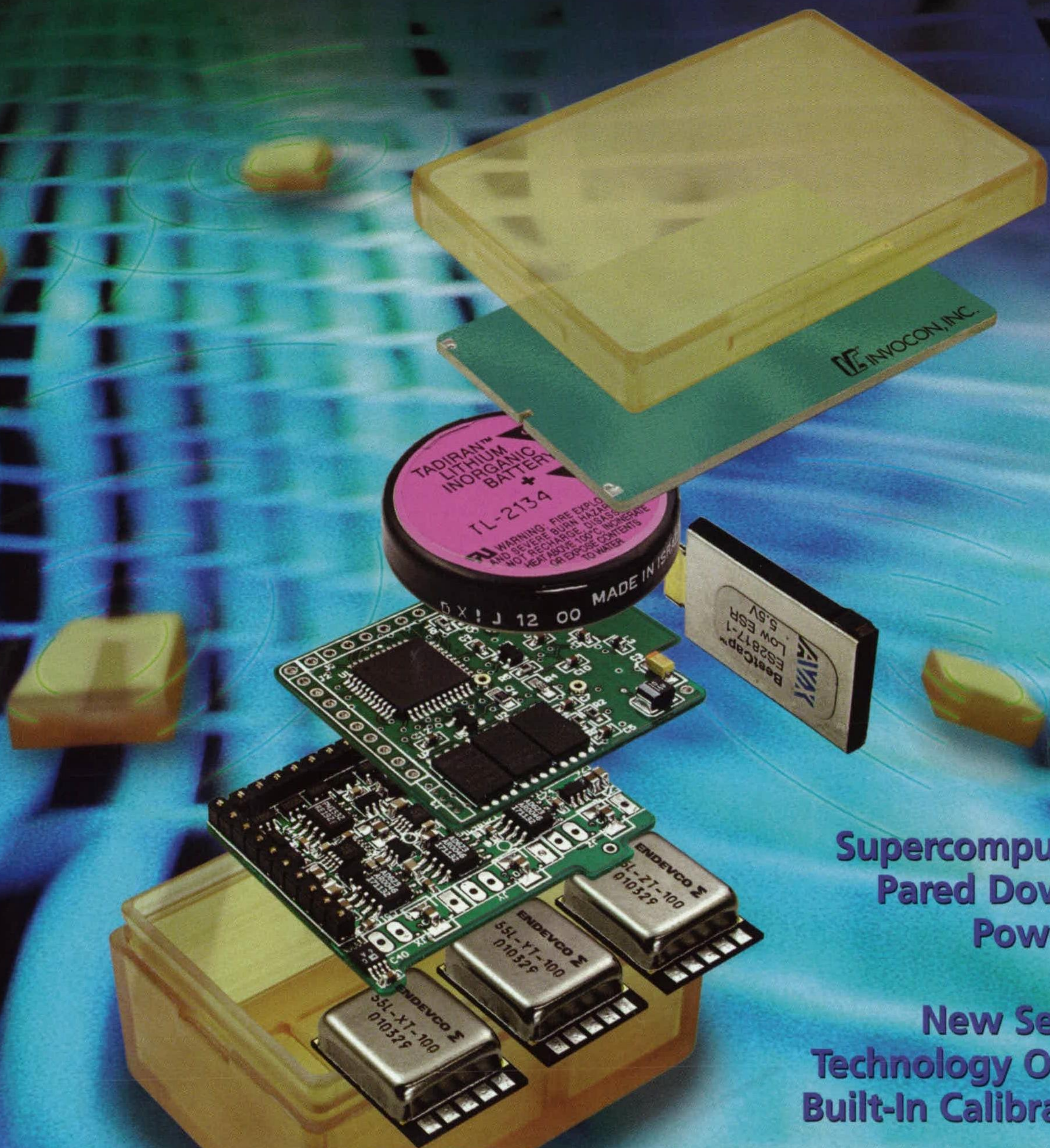
September 2001 Vol. 25 No. 9

NASA TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



Supercomputers: Pared Down & Powerful

New Sensor Technology Offers Built-In Calibration

Photonics Tech Briefs

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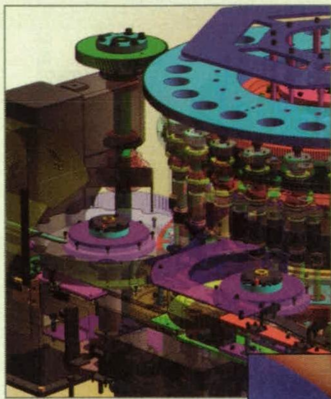
September 2001 • Vol. 25 No. 9

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

FEATURES

SOLUTIONS



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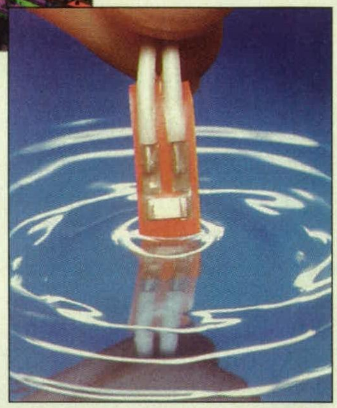

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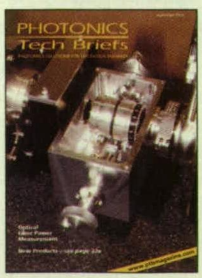

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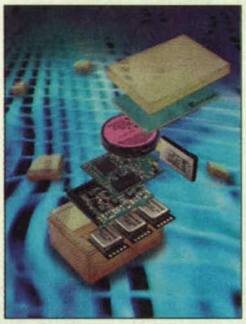

The PiezoPAK series of piezoelectric accelerometers from Endevco Corp. of San Juan Capistrano, CA (www.endevco.com) provides integrated vibration measurement of machines, structures, and vehicles. They also feature shielding, ground isolation, and five solder pads for power and signal connection. New sensing technologies — as well as more information on PiezoPAK and other new sensing products (page 37) — are described in this month's Special Coverage on Sensors, beginning on page 30.

(Image courtesy of Endevco Corp.)

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CO_2 Laser Applications of the Month

SYNRAD®
An Excel Technology Company

Marking Bar Codes on Cardboard & Wood with CO_2 Lasers

Marking text and graphics on cardboard and wood has always been an excellent application for sealed CO_2 lasers, but bar and Data Matrix™ codes have previously been considered unmarkable, as the resulting contrast was generally not high enough to be read without the use of a vision system. With Synrad's versatile laser marking software, WinMark Pro®, this is no longer the case. These codes can be made up of closely nested spots, which provide the needed contrast to make them readable with just a handheld scanner. The sample in the photo to the right was marked with a 25-watt CO_2 laser at a speed of 6" per second.

Bar and Data Matrix™ codes, marked on bare cardboard using WinMark Pro's Spot tool. The 2.3"x0.5" bar code was marked with a cycle time of 6 seconds, and the 0.4"sq. Data Matrix code in 1.5 seconds.

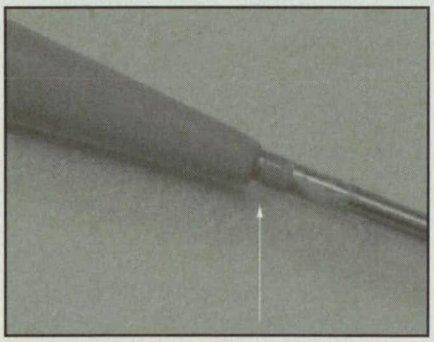
Laser Marking Data Matrix™ Codes on Steel

2D codes have gained popularity in the automotive and other industries, thanks to their ability to pack a large amount of information into a very small space. Synrad CO_2 lasers are ideal for marking these codes on a wide range of materials, including mild and stainless steels. Often considered the domain of Nd: YAG lasers, steel marking can be easily accomplished with a CO_2 laser - and, in some applications, as little as 50 watts is all that is required! CO_2 lasers can offer users a number of benefits over YAGs, including fewer safety requirements and higher contrast on some metals. Generally, for applications requiring less than 100 watts of power, CO_2 lasers are significantly less expensive than YAGs.

The Data Matrix™ Code (~0.2" sq.) on this torque converter was marked using WinMark Pro's Spot tool. The code was marked with 95 watts of power at a speed of 1" per second (7.4 second cycle time).

Laser Removal of Plastic Flashing

This medical device, made of MDPE (Medium Density Polyethylene), was rotated at 300 rpms, while the flashing was removed with 18 watts of laser power and 5psi air assist. The process results in a desirable smooth, rounded edge, with no loose plastic debris. HDPE, LDPE, and PTFE can also be cut with the same results. The metal rod was used to form the inside diameter of the part during production.



The flashing was removed from this plastic part with a Synrad 25-watt laser.

Discover more CO_2 laser applications! Sign up for our monthly online Applications Newsletter at ***www.synrad.com/signup1***

*All applications on this page were processed at **Synrad's Applications Laboratory**. Synrad, the world's leading manufacturer of sealed CO_2 lasers, offers free process evaluations to companies with qualified applications. Call 1-800-SYNRAD1 for more information.*

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

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Stennis Space Center
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NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

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(800) 678-6882

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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

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NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

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Joe Becker
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(408) 557-6700

Marty Kaszubowski
Hampton Roads Technology Incubator (Langley Research Center)
Hampton, VA
(757) 865-2140

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

NASA Patents

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Apparatus for Direct Optical Fiber Through-Lens Illumination of Microscopy or Observational Objects

(U.S. Patent No. 6,195,203)

Inventor: Hiroshi Kadogawa, Jet Propulsion Laboratory

In a microscope embodying the present invention, the output end of an optical fiber is oriented so as to directly project light along a straight line through an objective lens directly to the object being viewed. By passing the light through the objective lens, it can be diffused or otherwise defocused to provide more uniform illumination across the surface of the object, increasing the image quality. The direct undeflected and uninterrupted projection of light, without change of direction, eliminates the need for light-deflecting elements such as beamsplitters, mirrors, prisms or the like, to direct the projected light toward the object. Being able to eliminate these light-deflecting elements produces great advantages such as reductions in cost, weight, and complexity as well as increases in durability and ruggedness, and allows the invention to be used in conventional microscopes with minimal or no modification.

Method and Apparatus for Monitoring of Daily Activity in Terms of Ground Reaction Forces

(U.S. Patent No. 6,183,425)

Inventors: Robert J. Whalen and Gregory A. Breit, Ames Research Center

The device described in this patent is one that records and analyzes habitual daily activity in terms of the history of gait-related musculoskeletal loading. It uses foot-ground contact times to characterize daily walking and running, to compute gait-related energy expenditure, and to compute indices of daily physical activity related to skeletal loading. The device consists of a sensor placed in the shoe that detects contact of the foot with the ground. The sensor is coupled to a battery-powered waist-worn, ankle-worn, or shoe clip-on digital data logging system with real-time clock and microprocessor interface to random access memory, user pushbuttons, and an alphanumeric display. On user command, a program is initiated that first filters the sequence of stored timing events by removing contact times that are not likely to be gait-related loading cycles, such as climbing stairs. The remaining timing events are then analyzed as consecutive gait cycles. Further processing yields cumulative and average daily walking and running mean speed, steps, and duration. It may be possible to relate specific indices of fitness or health risk through application of a mathematical model of tissue functional adaptation.

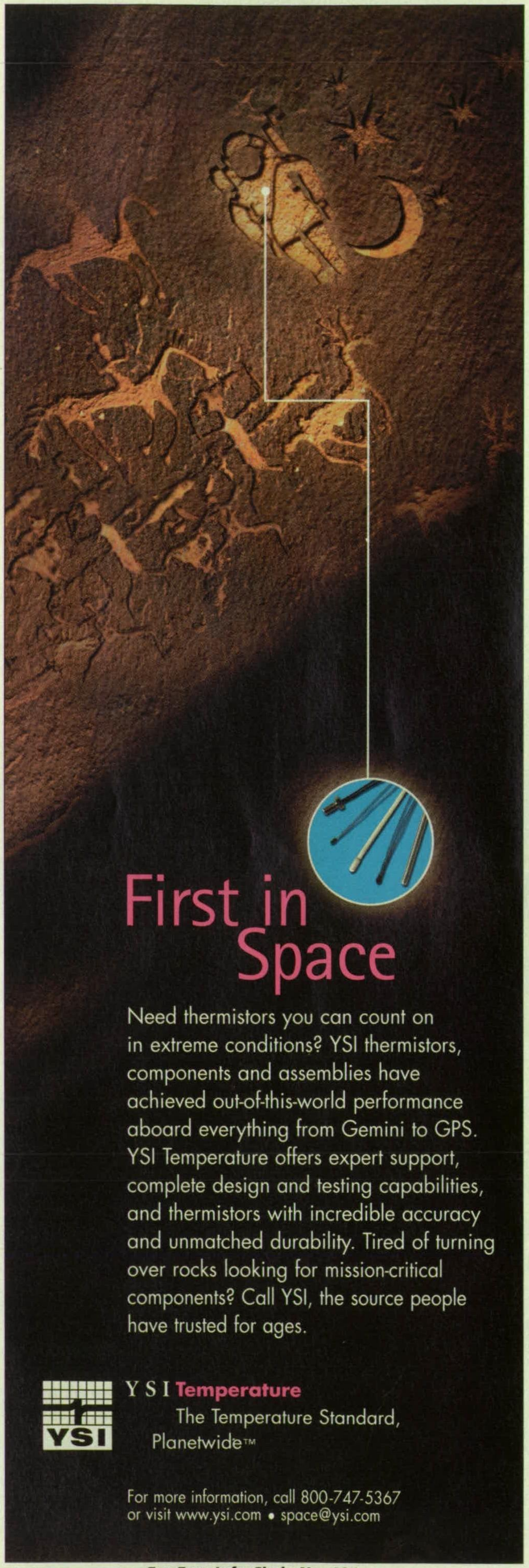
Selective Emitter Pumped Rare Earth Laser

(U. S. Patent No. 6,198,760)

Inventors: Donald L. Chubb and Martin O. Patton, Glenn Research Center

Lasing in rare earths such as neodymium, holmium, and erbium in a host material such as yttrium aluminum garnet has been achieved using flashlamp or laser diode pumping. As described in the disclosure, a selective emitter pumped rare earth laser provides an additional type of laser for use in many applications. Selective emitters are devices for converting thermal energy into narrow-band radiation. Most solid-state materials have nearly a constant spectral emittance (gray body). The spectral emittance of a rare earth is characterized by several emission bands in the visible and near-infrared region, resulting from electronic transitions from the lowest excited state. This new laser includes a rare-earth-doped laser rod having an energy absorption band matching the selective energy emission band. The emitter and the rod are arranged to allow energy from the emitter to impinge on the rod. Not only does using a selective emitter allow thermal energy to be input, but it also results in higher laser efficiency than flashlamp or diode-laser-pumped rare-earth ion lasers.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 10 for a list of office contacts.



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I am the current Hot Air Balloon World Champion. In August of 2002, I will defend my title against the top 100 balloon pilots in the world. To help me do my best, I'm seeking assistance in the development of a custom GPS tracking system. The primary purpose of the system is to automatically show the real-time positions of the balloon and both crew vehicles on a moving map. This technology already exists. The custom part is the addition of icons on screen that can be touched or clicked on to send a pre-set message with various information. The goal is to reduce the need for any voice transmissions, which detract from piloting. Any assistance would be appreciated.

Bill Arras
bill_arras@hotmail.com

Technologies Wanted

Periodically in Reader Forum, we feature abstracts of Demand-Pull Technology Transfer projects. These projects identify technology needs within an industry segment — such as Assistive Technology — and find solutions to meet those needs. The Rehabilitation Engineering Research Center on Technology Transfer, in partnership with the Rehabilitation Research Center on Hearing Enhancement, has developed the Hearing Enhancement Project to identify market needs like those described below that represent significant business opportunities. For more details on the project, or to submit technology solutions, visit the project web site at: **http://cosmos.buffalo.edu/hearing**.

Microphones

Hearing aids and most assistive listening systems (ALS) require high-resolution microphones. As in any sound transmission system, the hearing aid or ALS microphone is the key link that converts sound into an electrical signal. While different types of systems have various microphone requirements, there is a universal need for improved ALS and hearing aid microphones.

Advanced beam forming microphone arrays are a critical need. The optimal microphone will eliminate environmental noise and adjust sensitivity based on user needs. They should pick up orienting cues to track moving or changing speakers. The microphone arrays should not generate more noise than a single microphone.

Both body-worn and tabletop microphones require an improved wireless link to the hearing aid or ALS amplifier/processor. Tabletop microphones should provide speaker identity cues to listeners and be automatically adaptive so that they can detect and orient toward a new or moving speaker. Body-worn microphones should have an unobtrusive appearance and adapt to various indoor and outdoor environments.

UpFront

PRODUCT OF THE MONTH

The FlexPAC™ multi-slot portable rugged computer from Dolch Computer Systems, Fremont, CA, is available with an integrated 650-MB CD-RW drive that supports CD read at 24X, and writing to CD-R and CD-W disks at 4X speed. The drive has a 2-MB buffer and comes with Adaptec's Easy Creator software and Direct CD drag and drop software. Users can create multiple log files and burn them to disk on-site. The FlexPAC features four full-size add-in slots, up to five drives, and an active matrix color display. It uses the Pentium® III microprocessor running at 133 MHz, and has 8 MB of video memory. The rugged outer shell is an injection-molded, fiber-reinforced polycarbonate composite that measures 10.18 x 6.72 x 15.78". The unit weighs 18 pounds and features a full-size detachable keyboard, built-in pointing device, dual USB ports and serial ports, and an optional DVD.

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NASA Technology Licensed for Pharmaceutical Development

Synthecon, a Houston, TX-based manufacturer of three-dimensional tissue culture systems, has been granted an exclusive pharmaceutical license from NASA to produce recombinant human protein drugs in its proprietary Rotary Cell Culture System™ (RCCS™). The drug would treat autoimmune system diseases such as rheumatoid arthritis and lupus.

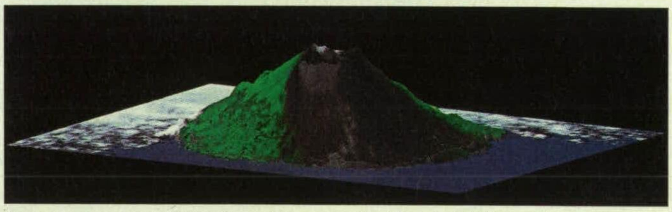
The Synthecon/NASA Rotary Cell Culture System is based on a 1986 NASA invention known as the bioreactor, a cell culturing apparatus that has a rotating cylinder developed at NASA's Johnson Space Center during research to simulate the way cell cultures grow in weightlessness. The system's rotation and shape reduce pressure points on the cells to stimulate the effect of weightlessness, producing high-density cell cultures that would not otherwise grow outside the body.

Synthecon holds an exclusive NASA license to manufacture the RCCS, with two more patents still pending. The Synthecon/NASA system is expected to increase the efficiency of producing recombinant protein drugs by at least ten times.

For more information visit Synthecon at www.synthecon.com, and NASA Johnson's Tech Transfer site at http://technology.jsc.nasa.gov/gen_info.htm.

Space is the Place for Volcano Research

Looking over the edge of Mt. St. Helens may reveal some interesting information about volcanoes, but the best view is from space, thanks to spaceborne instruments that let scientists see much deeper. "Previously, we had to depend on on-site observations not easily accomplished when a volcano was actively erupting," said Michael Abrams of NASA's Jet Propulsion Laboratory. "Now we can safely view them from space and obtain fast, accurate information from satellites."



A computer animation of a volcano on the island of Miyake-Jima, Japan. (Photo courtesy of NASA)

Instruments such as radiometers, spectrometers, and interferometers fly above the Earth year-round, providing scientists with continual coverage of the 500 active volcanoes around the world. The new data will enable long-term monitoring and creation of detailed images and videos. According to Dr. Vince Realmuto of JPL's Digital Image Animation Lab, the data will be turned into computer animation. "We are pioneering the use of powerful commercial animation software to visualize dynamic volcanic processes such as lava flows, ground deformation, and the appearance and growth of hot spots," said Realmuto.

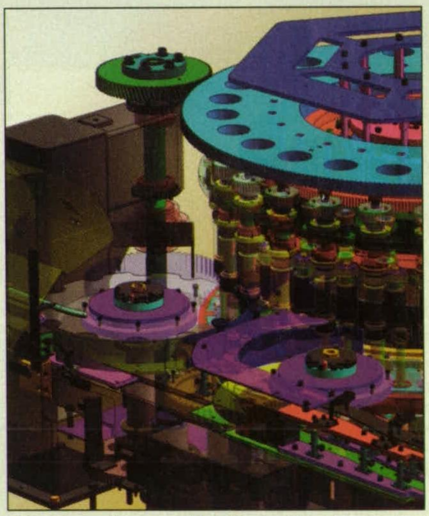
For more information, contact Rosemary Sullivant of JPL at 818-354-0474, or visit the Web site at www.jpl.nasa.gov/releases/2001/release_2001_147.html.

Solid Edge Version 10 - Solid to the Core

Steven S. Ross

The new version of Solid Edge, the MCAD package from UGS, adds functionality mainly to the base product. That's in contrast to the last major upgrade, in which most of the improvements were add-on products. UGS is particularly focused on trying to keep Solid Edge among the most feature-laden and easy-to-use packages for mechanical design.

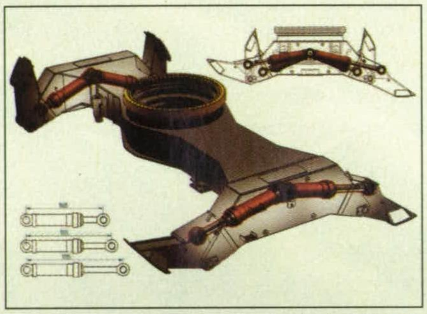
Computer-aided design (CAD) packages such as Solid Edge are, in a sense, specialized databases. Each part in an assembly is made up of numerous vectors and other data. Treating them all the same causes a bottleneck in large assemblies of hundreds or thousands of components. The answer is a "segmented" or "smart" database that loads the parts you need to view in your assembly. This also leads to what in Solid Edge is called "family of assemblies." When you revise a part in the "family," you automatically can generate a new set of drawings reflecting the entire family that uses the part.



This can-making machine from Alcoa Packaging Equipment shows the "cut-away" feature and variations in shading for clarity.

Say you have an instrument panel with the capacity to hold eight dial readouts, and these eight readouts can be chosen from among 20 instruments in three or four different layouts. You don't have to redraw each version, nor do you have to save the dial readouts as symbols. Instead, the existing work becomes the base for new modifications. If you change one item, the family of drawings is updated automatically.

The segmented database is the biggest news for designers of large assemblies, because it gets drawings up on the screen faster. More common tasks are made a bit easier with improvements to the drafting engine. Other improvements to the core product include a drawing view tracker, more options for coding parts



Note the two positions of the shock absorbers in this assembly (the footing of a mobile excavator from EKM GmbH).

and entire subassemblies or features by color, and better utilities for drawing pipe threads (especially tapered threads) and surface features. There's an improved translator to and from solid-modeling packages that use the ACIS kernel (Solid Edge uses UGS's own Parasolid kernel).

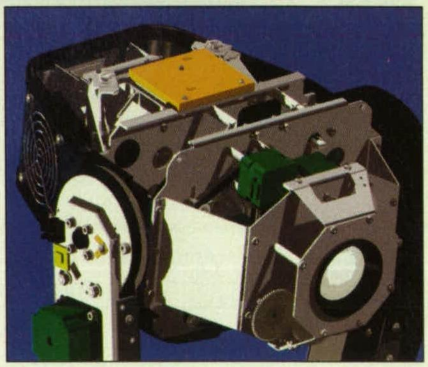
We did some translation of small assemblies from Solid Edge into TurboCAD 5.0 (which uses ACIS 5.2) and back, with no loss of geometry. But because the two kernels have different ways of describing certain entities, you can never rely totally on any translator. There's a new "healing" feature in Solid Edge 10 that automatically finds and corrects faults and some inconsistencies in imported data.

UGS says Solid Edge's interoperability with its top-end Unigraphics CAD system also has been improved. Solid Edge can open multi-body Unigraphics files directly now. The files remain fully associative with the Unigraphics model — change the model in Unigraphics and it can be dynamically updated in Solid Edge. Last year's version saw much-improved translators for STEP, IGES, Bentley DGN, and Autodesk DXF and DWG files. Version 10's DWG translator handles tolerances and hatch objects more easily, and recognizes OLE objects as well.

There are also a bunch of "little" enhancements. The view tracker will display reasons for out-of-date documents and generate a list of drawings that need updating. You can now highlight a part in a large assembly — pick it, right-click to get the shortcut menu, and click on "scroll to part."

If you've been using point coordinate data and capturing the data to a table to define a complex curve, or if you are used to describing shapes with a shape table, you might want to take a look at Version 10's handling of such data. Get it into an Excel spreadsheet, and Version 10 will generate the curve from the sheet and incorporate the sheet's raw data into the drawing file. You can use the sheet's raw data to generate a "smoothed" final curve.

The sheet metal module has gotten stronger, too. You can now save the 3D model of the bent metal as a "flat pattern" view in the same file to show the "unbent" version. Parts in assemblies can be displayed in "alternate positions" to check for clearances.



Note the sheet metal work and the standoffs between sheets on this light projector from ROBE in the Czech Republic.

Solid Edge runs on all recent versions of Windows, including Windows 98 and 2000. The price is $4,995 for the core product. Contact UGS in Huntsville, AL at 800-807-2200 or 256-705-2500; e-mail solidedge@ugs.com; or visit www.solid-edge.com.

Steven Ross is a visiting professor at Boston University, where he will co-direct a new Institute for Analytic Journalism for the coming year.

Who's Who at NASA

Ann Devereaux, Communications Systems Engineer, Jet Propulsion Laboratory

Ann Devereaux is a member of the technical staff for the Communications Systems and Research Section at NASA's Jet Propulsion Lab in Pasadena, CA. She has worked on spacecraft, ground-based, and satellite communications projects, and currently is part of the prototype demonstration systems team for the Wireless Augmented Reality Prototype (WARP) project.

***NASA Tech Briefs:* What is the Wireless Augmented Reality Prototype (WARP)?**

Ann Devereaux: The idea was developed when NASA decided it would be good if astronauts could monitor their own bio-medical information. They could see if their temperature or heart rate was getting too high, and could be more aware of their own medical situation while they were performing various tasks. From there, the idea grew to include displaying this information in a video display, not only for the astronauts performing the tasks, but also for other people in the International Space Station and the flight surgeon on the ground. As the idea continued to grow, more and more information was going to be incorporated into this display. Our challenge was to create a system that could handle not only the textual information to be displayed, but also the amount of video that was going to be incorporated.

NTB: What types of technologies are used in the WARP?

Devereaux: When I first came onto the project, they already had developed a big computer in a box. It was wearable in the sense that a backpack is wearable. It wasn't what we wanted. It had low-resolution video, and they had used a commercial headset to demonstrate the prototype. That was the phase one system. The current phase two system includes a hip pack and a headset. On the headset there is an eyepiece that lets you view a VGA display, a camera on one side, and a microphone and earpiece on the other. The hip pack contains the interface box, which talks back to a computer that does all the hardcore data processing.

In the next version, we'll be compressing down the wearable part of the WARP and boosting up the data rate so that we can handle an SVGA viewer on the headset. We also plan to compress the circuitry down so that the interface box will sit on a network, just like a router.

NTB: What problems have you encountered in developing this technology?

Devereaux: One of the things we've been concerned about is the overload and underload of information on astronauts in the station. Obviously, there are a lot of things going on at all times. That's the information overload. How do you possibly know what's in every bin and what's giving you alarms? The other part is information underload. Because it is awkward to get around, you can't see into very many things from where you are.

NTB: Is there a demand for this type of technology from the commercial sector?

Devereaux: We've had a lot of demand lately from other NASA centers and people affiliated with NASA who have seen the WARP and said, 'I have a great application for that.' In fact, a non-profit company has a system through which you can do long-range communication between an ambulance and a hospital. They do that by putting repeaters all over the city. They said that with our system, they could put a set-up similar to the WARP on a paramedic. So now we have our short-range connection to the ambulance. And then the ambulance, a big sturdy thing, can do the long-range connection to the hospital.

On the commercial end of things, a company called Select University Technology Inc. (SUTI) has picked up the option for the license to this technology, and they are building up a business plan around what they will do with it.

*A full transcript of this interview appears online at **www.nasatech.com/whoswho**. Ms. Devereaux can be reached at ann.devereaux@jpl.nasa.gov.*

Commercialization Opportunities

Si Microsensor Baseplates With Low Parasitic Capacitances

An improved design reduces parasitic capacitances between adjacent coplanar electrodes and thermal-expansion mismatches, which are present in baseplates of older design.
(See page 31.)

Carbon Nanotube Bimorph Actuators and Force Sensors

The proposed devices could make it possible to generate, sense, and control displacements and forces on a molecular scale and could readily be integrated with conventional electronic circuits.
(See page 33.)

Built-in "Health Check" for Pressure Transducers

Calibrations could be verified approximately, without removing transducers to calibration laboratories. This approach would give timely warnings of pressure-transducer malfunctions and reduce the frequency at which they are replaced or subjected to full laboratory recalibration.
(See page 33.)

Improved Field-Emission Cathodes

Microscopic cathodes based on field emission are being developed as miniature or scalable sources of electrons for such diverse applications as spacecraft thrusters, semiconductor-fabrication equipment, flat-panel display devices, and miniature x-ray sources and electrodynamic tethers and mass spectrometers.
(See page 38.)

Enhancing the Removal of Chlorocarbons From Groundwater

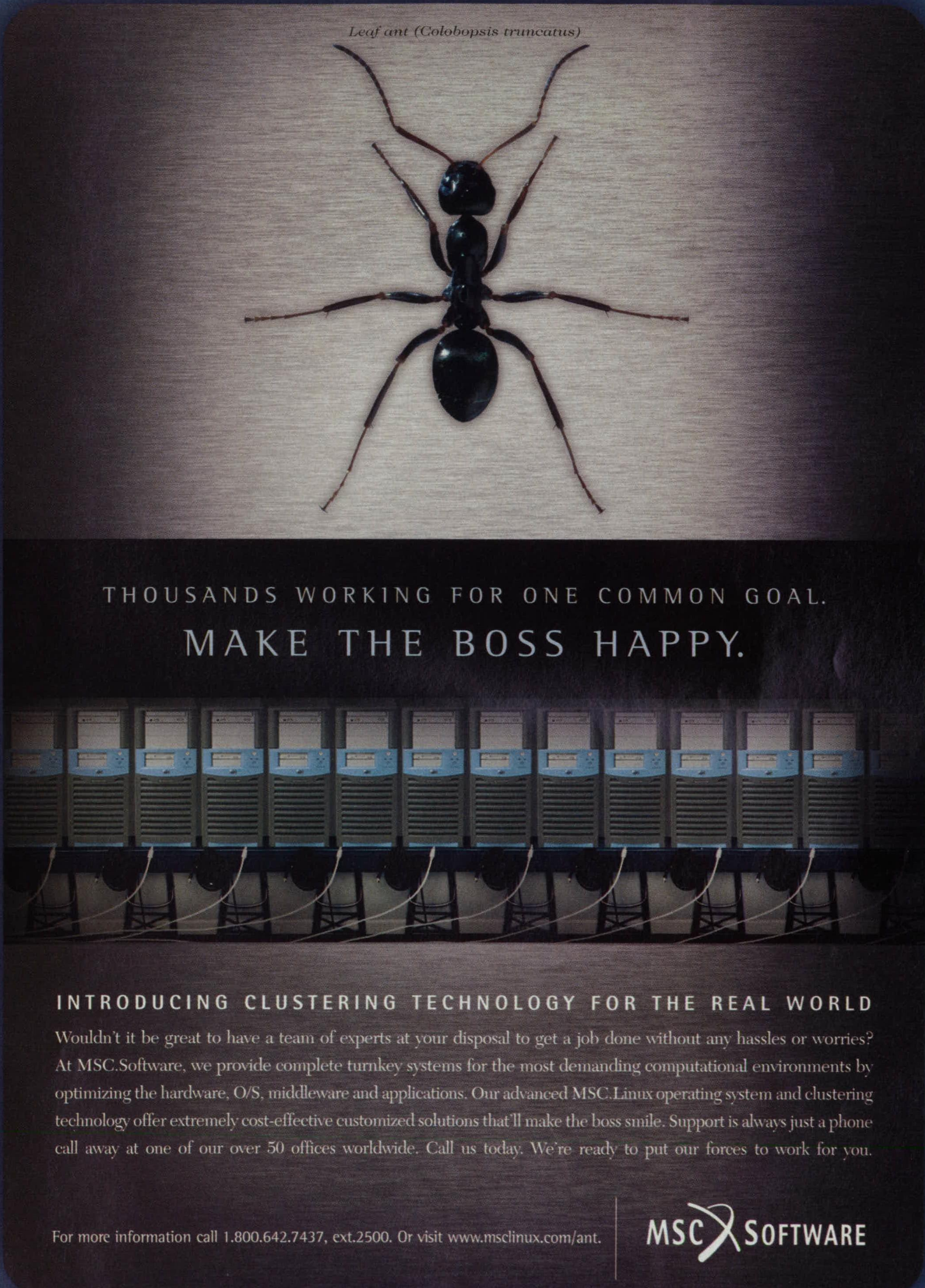
Ultrasound could enhance the removal of chlorinated hydrocarbon contaminants from groundwater. The process is attractive because it does not involve above-ground treatment or the use of pumps.
(See page 45.)

Vapor-Compression Solar Refrigerator Without Batteries

This refrigerator incorporates control circuitry connected directly to a solar photovoltaic panel and to a compressor. The design promises to make the cost of solar-powered refrigeration competitive in urban and remote areas and could be extended to freezers, ice makers, and air conditioners.
(See page 48.)

Thermal-Stress Technique for Cutting Thin Glass Sheets

An electrically heated tungsten tip can cut flat and curved glass 30 to 600 μm thick reliably, accurately, and economically, as opposed to lasers or diamond tips.
(See page 51.)


Leaf ant (Colobopsis truncatus)
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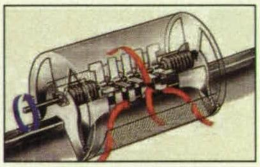
Wind-Driven, Rooftop Generator Addresses Sporadic Power Shortages

Dallas Twynman



California's aging electrical grid and inadequate power generation are causing residents to suffer power outages and rising utility bills. One possible alternative technology involves rooftop-mounted, wind-driven generators that blend into the roof line and match common roofing material. Specially designed cylindrical roofing tiles with a V-notch to fit the ridge would be secured to the joists and each other, forming a continuous, rigid support along the top of the roof. A small electrical generator would be mounted inside the housing with an air inlet and outlet on either side, covered by grills to keep animals out and protect against weather.

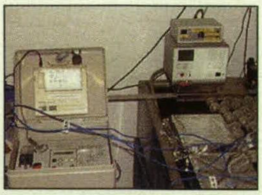
The generator features blades fixed to a rotating shaft and coils mounted at both ends of the shaft. The air flowing through the inlet turns the impellers, which drive the shaft in the coils, creating electrical current. Connections coming off the generator tie into the building's electrical system, diverting excess energy back to the local, regional, or national grid. The consumer would then be credited for the amount of energy sold back to the utility.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/inventorlink.html

Additive Improves Concrete Versatility and Performance

DSM & Smals

Concrete comes in a variety of fabrications to meet environmental conditions. To facilitate these uses, concrete manufacturers incorporate additives in the form of finely divided materials less than 125 microns in size that are used to improve flow, elasticity, durability, shrinkage, reduction, and aesthetic appearance in concrete. Creating and incorporating additives can be expensive and inconsistent.

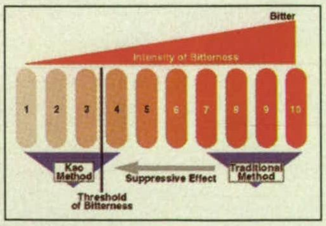


DSM and Smals of the Netherlands have developed a low-cost automated process for producing additives that can vary in shape, size, and chemical composition. Combinations of different additives and chemicals can be used with accurate proportioning so that properties can be modified quickly to suit many applications. The new manufacturing process improves concrete performance enough to enable the use of less cement in the mixture without sacrificing any concrete properties. The process currently is being used to produce additives for high-flow, self-compacting concrete used in sewer pipes, internal wall slabs, retaining walls, lintel beams, and concrete slate roofing.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/dsm.html

Fatty Compounds Suppress Bitter Tastes

Kao Corporation



Taste has a profound effect on our health, nutrition, and wellbeing. Nutritional foods, life-saving drugs, and cosmetics often are rejected simply because they have a bad taste. Traditional methods of combatting bitter tastes have included masking them with coatings, fillers, and syrups that often provide only temporary respite from the bitterness.

A new flavor-suppression technology uses fatty compounds called acidic phospholipids or lysophospholipids obtained from natural sources such as egg yolks, soybeans, wheat buds, and animal tissues by separation or extraction. The lipids are adsorbed by the bitter elements, effectively suppressing their taste. Both compounds can be added to food, drinks, cosmetics, and pharmaceuticals in the form of powders, granules, pellets, pastes, syrups, solutions, and emulsions.

Get the complete report on this technology at:
www.nastech.com/techsearch/tow/kao.html

Real-Time Multimedia Over the Internet

Byung-Dal Jung, LG Elite

LG Elite of Korea has developed a flexible, stable, video-on-demand (VOD) software system that enables content providers and viewers to interact with text, images, audio, and video over the Internet or an intranet. At the heart of this technology is a new way to use a kernel driver. In a typical computer system, the portion of the operating system that provides system-level commands, called a kernel driver, enables computers to run faster by executing and displaying images in the same machine. The disadvantage of kernel-based systems is that it is difficult to share computer resources over a network. LG Elite has incorporated a kernel driver that doesn't require user and kernel interaction in its VOD technology.

Ideal for advertising and education – both as a distance learning and in-house corporate educational tool – this new VOD system is perfect for universities, museums, government agencies, and private companies looking to use a broadcasting tool to reach a large audience.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/lgelite.html

Pared-Down and Powerful: The New Supercomputers

The performance of personal computers (PCs) and workstations has grown to an unprecedented level in recent years. With a good computer and the necessary accessories, just about any company can create a system with gigaflop performance (a gigaflop equals one billion floating-point operations per second). So at what point do these high-performance computers become supercomputers?

Supercomputers are measured not only in capacity, but also in capability. Solving problems that are simply very large can be accomplished by most high-end PC clusters. But problems that are both large *and* complex require supercomputers.

Cray Research, known to many as the pioneer of the supercomputer, introduced its first monstrous mainframe, the Cray-1, in the mid-1970s. The computer featured some revolutionary ideas, including the "C" shape of the system, which enabled integrated circuits to be closer together — no wire in the system was more than four feet long. And to handle the intense heat generated by the system, Cray developed an innovative refrigeration system using Freon.

Cray Inc., as it's known today, continues to be a market leader in supercomputers, but the new systems are smaller and more powerful than company founder Seymour Cray could have imagined.

"The definition of a supercomputer can be all over the place," said Steve Conway, vice president of corporate communications for Cray. "I think a supercomputer is very simply defined as the fastest class of computers at any one time. They come in so many flavors and colors that to get beyond that leads to madness. It seems silly to claim that there is one final, narrow definition to what supercomputers are, because it keeps changing."

Today's supercomputers are used not only in research laboratories and top-secret government installations, but also in most types of business and industry — from banking and automotive, to medical and manufacturing. Today's systems are parallel devices that link several hundred to several thousand processors — joined together with a network — and working cooperatively to run a system, calculate enormous equations, or attempt to decrypt a code.

IBM often is regarded as today's supercomputer leader, and has the multi-million-dollar contracts to prove it. In 1998, the U.S. Department of Energy (DOE), under its Accelerated Strategic Computing Initiative (ASCI), contracted IBM to build the world's fastest supercomputer for the government to test its nuclear capability using 3D modeling and simulations. In June 2000, IBM announced the completion of that system, dubbed ASCI White. The supercomputer actually consists of 512 separate computers linked together to cover an area the size of two basketball courts. ASCI White has a computational capability of 12.3 teraflops (one teraflop is equal to one trillion operations per second), and features 8,192 processors.

Last July, IBM made available to the general public a commercial version of ASCI White by putting the technology into a new version of its RS/6000 SP. Companies in the automotive, aerospace, pharmaceutical, financial, and telecommunications industries were early customers, with a basic four-processor system costing $160,000.

According to David Gelardi, director of high-performance computing for the Server Group at IBM, size and scale are no longer accurate defining points for supercomputers. "I think supercomputing purists are disappointed that there isn't this exotic machine that they can call a supercomputer anymore."

There certainly is nothing exotic about today's supercomputer "Beowulf

(Continued on page 27)

Supercomputing's Bible

Any supercomputer manufacturer knows the NCSA — the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign. Opened in 1986 as one of the five original National Science Foundation Supercomputer Centers, NCSA has grown its reputation as the foremost resource on supercomputing, issuing their TOP500 Supercomputer Sites list, which has been updated twice yearly since its creation in 1993.

The mission of the TOP500 is to provide a basis for statistics on high-performance computers. The list includes the 500 most powerful supercomputer systems and where they are installed.

The most recent list, issued in June of this year, ranks IBM as the top supercomputer manufacturer, with 201 of the 500 top installations. The top ten also includes Sun (81), SGI (63), Cray (45), Hewlett-Packard (41), NEC (18), and Compaq (10).

The most impressive statistic provided in the list is the installation areas, which enforces the idea that supercomputing is not simply the realm of academia anymore. Among the top ten industries with the most supercomputer installations are telecom (49), automotive (21), World Wide Web applications (13), aerospace (11), and electronics (7). Also on the list with multiple supercomputer installations are mechanics, manufacturing, and transportation.

For more information on the NCSA — and to view the complete TOP500 list — visit www.ncsa.uiuc.edu.

clusters" — hundreds of PCs wired into a network controlled by Linux software — but that's the wave of the future for commercial industry. "We're seeing Intel-based servers connected together, running Linux, as the next wave of high-performance computing," said Gelardi. "In the public sector, Linux is dominating."

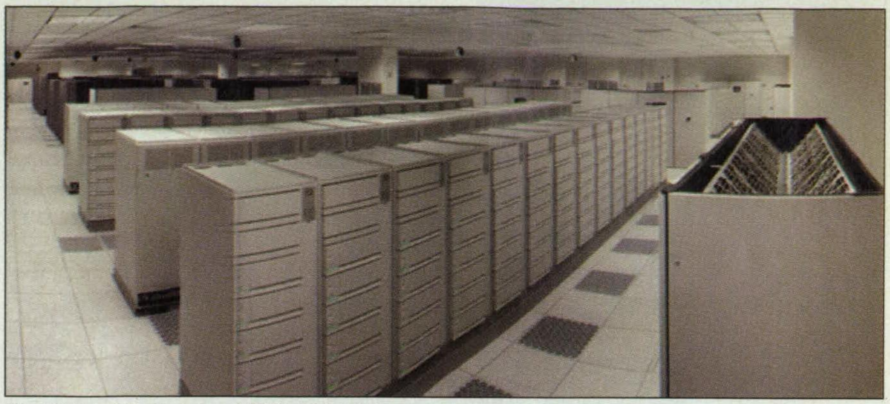
MSC.Software's introduction of MSC.Linux software underscores the importance of the Linux operating system in supercomputing. MSC's version of Linux provides a means for creating and maintaining high-performance supercomputing environments. The software combines large memory, large file support, data transfer, and cluster tools in one Web-based distribution.

Jay Clark, director of marketing and business development for MSC.Linux, believes that simply buying a cluster of machines won't do any company much good if they don't know how to best utilize the hardware. "Simply buying a cluster is like buying a high school band. You get an orchestra, but is it really going to be what you want. For a true symphony, you need fine-tuning of the operating system, the selection of middleware, proper selection of the hardware and all its components, and what types of processors you should be using. That's where we get involved."

At Cray, the company is hedging its bets when it comes to Linux and its development. According to Conway, the company is continuing to offer systems that can have up to thousands of processors, but they provide a kernel of Linux on each processor and overlay that with the basic Cray-UNIX operating system.

"From a user's standpoint, it looks just like Linux. From the standpoint of a system administrator, it looks like the Cray UNIX system," explained Conway. "Everyone is, and should be, excited about Linux. We're waiting for Linux to grow up. We want to be good open-source citizens, but we're not going to try to base our strategy on something that doesn't exist yet," he said.

Companies like Hewlett-Packard (HP) and SGI provide supercomputing power via UNIX-based servers. HP's Superdome and 9000 V-Class Enterprise Servers are engineered for large-scale applications and databases, or as compute engines. SGI — which merged with Cray in 1996 and then sold the assets of the Cray business unit to Tera Computer in 2000 — has seen their Onyx® and Origin™ workstations and servers used in supercomputing applications by industry as well as government agencies such as NASA.



The third and final stage of IBM's ASCI White supercomputer was delivered on August 31, 2000 to the Department of Energy. The completed system takes up the area of two basketball courts.

Supercomputing at Work

While the types of computer systems classified as supercomputers have changed with time, so have the users of these multi-processor systems. Commercial, as well as engineering users, now employ supercomputers for database applications, data mining, and scheduling tasks. No longer are supercomputers being used simply by scientists in white lab coats, although academic and government research remain an important realm for high-performance computing.

A 512-processor supercomputer based on SGI's Origin™ 3800 system was installed earlier this year at NASA's Ames Research Center in California for uses including faster and better development of spacecraft, computational fluid dynamics, global climate modeling, and computational astrobiology. The system was used this summer to evaluate the global impact of natural and human-induced activities on our climate.

"What used to take a year to calculate on a single processor might be done in less than a day on a 512-processor machine," said Dr. Ghassem Asrar, associate administrator for Earth science at NASA Headquarters. "With large NASA computer codes, we now have a technique that speeds up the processing time ten-fold."

But NASA and SGI don't plan to stop there. Ames computer scientists plan to combine two of the 512-processor machines to make an even more powerful supercomputer. According to Asrar, "This 1,024-processor system will serve as a research testbed and once mature, will be shifted to routine operations. The next step in research and development will be linking clusters of similar processors located across the nation to create a 'virtual supercomputer' with a computational capability greater than the sum of the individual clusters."

General industry could benefit from a new IBM initiative to support a technology called grid computing, which the company believes could be the next evolutionary step in the development of the Internet. The grid computing vision is that everyone at a desktop machine or handheld computer eventually could have the power of a supercomputer at his or her fingertips by amassing the processing power and information resources attached to networks. Currently, the types of computer hardware and software needed to achieve grid computing are in their infancy. IBM estimates that it will spend $1 billion over the next two to three years on a move to grid computing,

Today's supercomputers like this SGI Onyx2® system more closely resemble workstations, and are in use in many industries.

which originated in supercomputing centers.

Grid computing is expected to add a new dimension to the Internet, which currently is used for communication. The Web, at the same time, is used to provide access to text, images, and audio. Said Ken Kennedy, a Rice University professor, "The goal is that the grid becomes the computing engine for the Internet in the way that the Web is the information engine. The real long term is that this becomes the problem-solving mechanism for society."

In the short term, companies are still looking for speed and performance. "People want computers that are really powerful to tackle big problems and big workloads," said Cray's Conway. But is supercomputing ever "super" enough? Conway hopes not. "No matter what company you work for, supercomputers end up being the computers that are just one generation behind what customers really want."

*Visit **www.nasatech.com/features** for more comments from industry leaders on supercomputing.*

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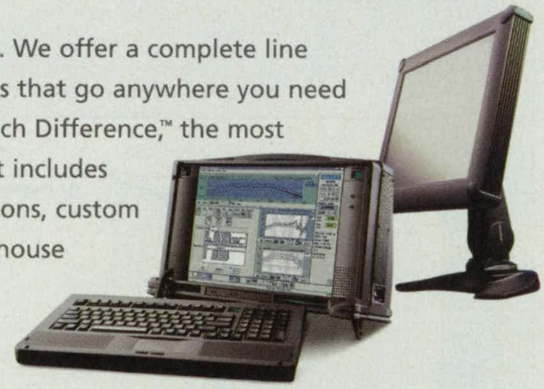

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Special Coverage: Sensors

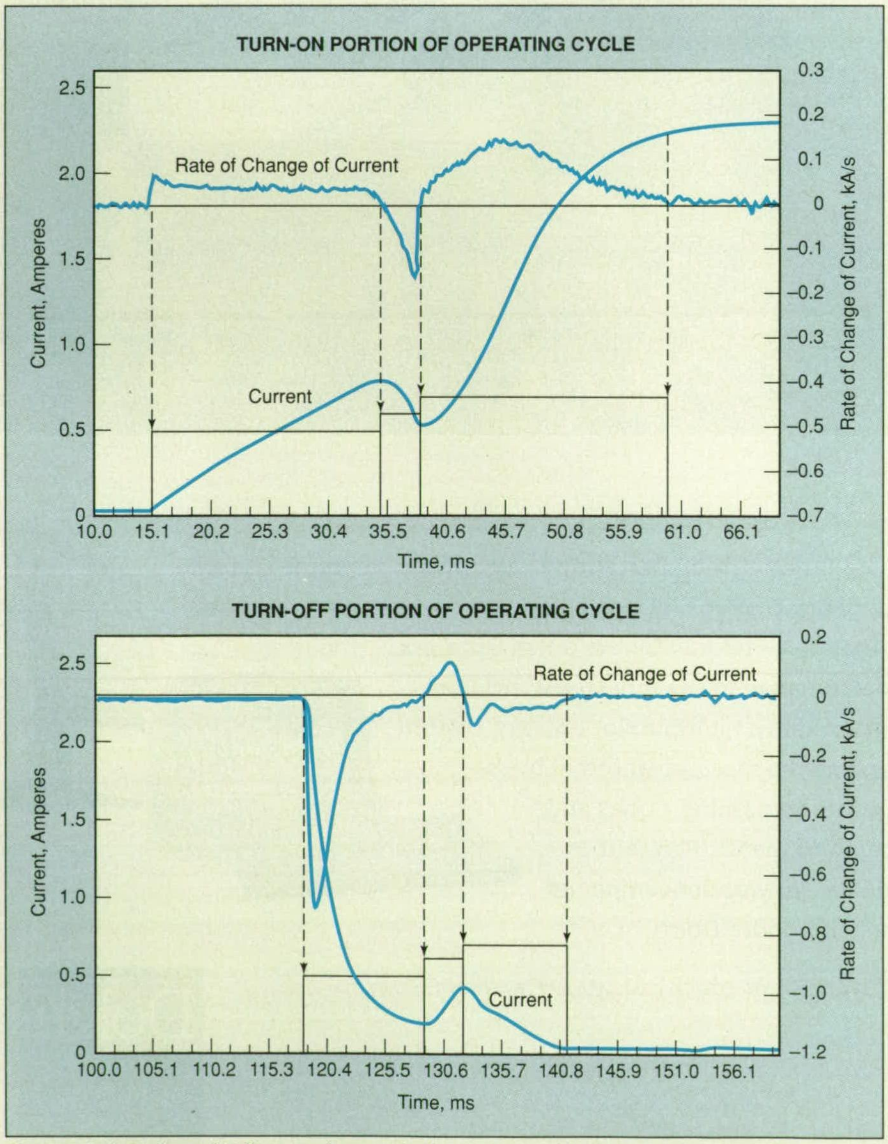
Current-Signature Sensor for Diagnosing Solenoid Valves

Changes in current signatures are indicators of electrical and mechanical deterioration.

John F. Kennedy Space Center, Florida

The "smart" current-signature sensor is an instrument that noninvasively measures and analyzes steady-state and transient components of the magnetic field of (and, thus, indirectly, the electric current in) a solenoid valve during normal operation. The instrument is being developed to enable continuous monitoring of integrity and operational status of solenoid valves without need for interrupting operation to conduct frequent inspections. The instrument is expected to be capable of warning of imminent solenoid-valve failures so that preventive repairs can be performed. The basic instrument concept should also be adaptable to similar monitoring of electromechanical devices, other than solenoid valves, that are required to be highly reliable.

This current-signature sensor exploits the fact that unique characteristics (signatures) of the solenoid current — especially of the turn-on and turn-off current transitions — are affected by electrical and mechanical deterioration of the solenoid and valve parts. Current signatures include characteristic peaks and valleys (see figure) that repeat at well defined times during every operating cycle and have well defined magnitudes and shapes. As electrical and/or mechanical deterioration occurs, the peaks and valleys change both in time and magnitude; these changes can serve as indications of potential trouble.



Characteristic Peaks and Valleys can be seen in the current and in the rate of change of the current in a solenoid at turn-on and turnoff.

The hardware portion of this current-signature sensor comprises a signal-acquisition assembly and a signal-conditioner/controller assembly. The signal-acquisition assembly contains a linear Hall-effect sensor for measuring the magnetic field generated by the current in the solenoid, plus a flux concentrator to maximize the response of the sensor and a shielding cage to prevent unwanted external magnetic fields from reaching the sensor. A temperature sensor is included to enable compensation for the temperature dependence of the response of the Hall-effect sensor.

The signal-conditioner/controller assembly includes an analog module, a microprocessor controller module, and a power-supply module. A real-time calibration module was being designed at the time of reporting the information for this article. The analog module conditions the low-level signal coming from the signal-acquisition assembly. The preamplification and final amplification stages in the analog module contain digitally controlled potentiometers that are used to compensate in real time for variations, with temperature, of the offset and gain components of the sensor and the signal-processing circuitry.

The settings for the digitally controlled potentiometers are provided by the microprocessor controller module: Prior to operation, calibration measurements with known inputs are taken at various temperatures to characterize the temperature dependence of the sensor and the signal-processing circuitry. A compensation curve is then calculated and programmed in the microprocessor controller module for use in the real-time temperature compensation as described above.

The real-time calibration module is envisioned to be connected to a calibration coil that would be part of the signal-acquisition assembly. Upon command by either the microprocessor controller module or a technician, the real-time calibration module would perform a complete sequence of calibration measurements to determine whether the sensor or other parts of the instrument had deteriorated.

In addition to temperature compensation, the microprocessor controller module is responsible for both real-time and trend analysis of the current signature. In operation, every valve cycle would be monitored and "health" parameters would be calculated to determine whether the monitored solenoid valve is performing within the nominal parameters. The "health" analysis and prediction of failure would be performed by software residing in the microprocessor controller module.

Thus far, a simple algorithm has been devised to detect specific characteristics of the current signal: A simple first derivative of the signal with respect to time (that is, the rate of change of the signal) would be calculated in real time. Peaks and valleys of the current signal would be detected and time-tagged by looking for zero crossings of the rate of change. Slope and steady-state values of the signal would also be monitored. These current-signature parameters would be compared against stored parameters and parameter-uncertainty ranges that would represent the behavior of a typical solenoid valve. The results of the comparisons would be summarized as indications of a nominal, border-line, or failure condition. An account of these results and of the statistics of nominal, border-line, and failure cycles would be stored as well as forwarded to a technician for further action.

This work was done by Jose M. Perotti, Angel R. Lucena, Curtis M. Ihlefeld, and Mario J. Bassignani of **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-6373. Refer to KSC-12152.

Si Microsensor Baseplates With Low Parasitic Capacitances

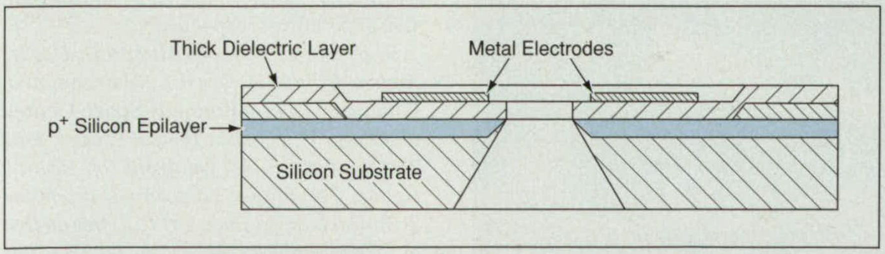
An improved design also reduces thermal-expansion mismatches.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved design for baseplates in silicon microsensors reduces parasitic capacitances between adjacent coplanar electrodes. It also reduces thermal-expansion mismatches, which are present in baseplates of older design.

Heretofore, baseplates of silicon microsensors have been made from quartz or ceramic because of concern over parasitic capacitance, which can adversely affect sensor performance. The disadvantage of using quartz or ceramic is that the coefficients of thermal expansion of these materials differ from that of silicon. The thermal-expansion mismatch subjects the sensors to undesired stresses that vary with temperature.

According to the improved design, the baseplate of a silicon microsensor is made from silicon, eliminating the thermal-expansion mismatch. The silicon baseplate (see figure) includes a silicon



This **Micromachined Silicon Structure** is typical of baseplates in silicon microsensors according to the improved design. The thick dielectric layer and the p^+ silicon epilayer are essential elements of the design to reduce the capacitance between the electrodes.

substrate, a heavily p-doped epilayer, and a thick dielectric layer made of silicon dioxide or silicon nitride. Metal electrodes are deposited on the outer surface of the dielectric layer.

The p^+ epilayer serves as an electrically conductive ground plane, which contributes to reduction of the capacitance between the electrodes. The dielectric layer electrically insulates the electrodes from the ground plane. The thickness of the dielectric layer is an important element of the design: The dielectric layer must be as thick as possible, consistently with other design considerations, in order to minimize the capacitance between the electrodes and the ground plane.

This work was done by Roman Gutierrez and Tony K. Tang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20689, volume and number of this NASA Tech Briefs *issue, and the page number.*

Robot for Positioning Sensors in a Plant-Growth Chamber

John F. Kennedy Space Center, Florida

The Advanced Life Support Automated Remote Manipulator (ALSARM) is a three-degree-of-freedom robotic system that positions an array of sensors inside a closed-system hydroponic chamber used in research on the production of biomass and the use of hydroponic subsystems of life-support systems. The array includes sensors to measure the light intensity, air temperature, infrared temperature, relative humidity, and airflow. The ALSARM operates under either automatic control by a personal computer or manual control through a teaching pendant (essentially, a hand-held box that contains switches and indicators wired to a plug for connection to the rest of the ALSARM control circuitry). The motivation for developing the ALSARM was the need to eliminate the leakage of the chamber atmosphere and the potential for contamination associated with the prior practice of opening the chamber so that technicians could enter to take environmental measurements. One especially notable feature of the ALSARM is a horizontal telescoping arm, through which power and signal cables for the sensors are routed. The cables are extended and retracted with the motion of the telescoping sections by use of a servomotor and gravitation, respectively.

This work was done by Michael D. Hogue, Andrew J. Bradley, Robert L. Morrison, and William C. Jones of **Kennedy Space Center** *and Roger W. Johnson, Ronald P. Enos, and Zhihua Qu of the University of Central Florida. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
KSC-12084

Carbon Nanotube Bimorph Actuators and Force Sensors

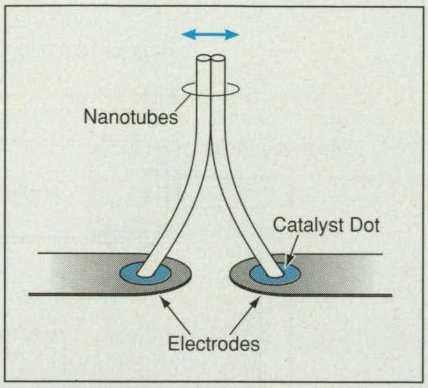
These devices would make possible novel microelectromechanical systems, possibly even microscopic robots.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposal has been made to develop bimorph actuators and force sensors based on carbon nanotubes. The proposed devices could make it possible to generate, sense, and control displacements and forces on a molecular scale, and could readily be integrated with conventional electronic circuits. These devices could also enable the development of a variety of novel microelectromechanical systems, including low-power mechanical signal processors, nanoscale actuators and force sensors, and even microscopic robots.

The proposed devices would exploit the dependence of nanotube length on charge injection that has been observed in mats of disordered carbon single-wall nanotubes (SWNTs) [Baughman, R.H., et al., "Carbon Nanotube Actuators," *Science* 284, 1340 (1999)]: the nanotubes become elongated or shortened when biased at negative or positive voltage, respectively. This result suggests that one could produce opposing changes in length in pairs of side-by-side, oppositely-biased nanotubes, resulting in a lateral deflection of the unsecured tube ends, as shown in the figure. Fabrication of such a nanotube bimorph device requires the ability to produce and join the tubes in the desired configuration with one end of each tube connected to a suitable electrical contact.

The proposed bimorph device could be fabricated by growing two nanotubes by chemical vapor deposition (CVD) on closely spaced catalyst dots over prepatterned bias electrodes on a substrate. It is likely that during the growth of the nanotubes, the van der Waals attraction would cause the nanotubes to become attached to each other along their sides, as shown in the figure. Because the electrical conductivity of a nanotube perpendicular to its length is much lower than the electrical conductivity along its length, this configuration should make it possible to maintain a significant differential voltage across the two nanotubes, as needed to cause a differential length change in the pair. Conversely, the application of a lateral external force to the tip of the pair should give rise to a voltage between the electrodes so that this device can also function as a sensitive force detector.



Carbon Nanotubes would grow out from catalytic metal dots on electrodes, eventually becoming attached to each other by van der Waals forces to form a bimorph actuator or sensor.

To be able to fabricate nanotube bimorph actuators with the configuration shown in the figure, it will be necessary to develop the means to control the positions and orientations of individual nanotubes on such substrates as silicon wafers. This is likely to entail the use of electron-beam lithography, lift-off, and etching for fabricating catalyst dots 5 to 15 nm wide on pre-patterned electrodes. Suitable catalyst materials could include Ni or alloys of Ni, Co, Fe, and/or Mo. In the contemplated CVD process, suitable precursor and carrier gases (e.g., methane, ethylene, or carbon monoxide plus hydrogen plus either argon or nitrogen) would interact with the substrate (which would be heated to a temperature between 600 and 950 °C), yielding selective growth of nanotubes out from the catalyst dots. There are numerous potential variations on this basic fabrication scheme, including orienting the dots so that the nanotubes grow parallel (instead of perpendicular) to the substrate surface and incorporating other materials to modify the electrical and mechanical properties of nanotube pairs.

This work was done by Brian Hunt, Flavio Noca, and Michael Hoenk of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-21153, volume and number of this NASA Tech Briefs *issue, and the page number.*

Built-in "Health Check" for Pressure Transducers

Calibrations could be verified approximately, without removing transducers to calibration laboratories.

John F. Kennedy Space Center, Florida

"Health check" would be built into pressure transducers, according to a proposal, to enable occasional, rapid, *in situ* testing of the transducers between normal pressure-measurement operations. The health check would include relatively simple devices that, upon command, would provide known stimuli to the transducers. The responses of the pressure transducers to these stimuli would be analyzed to quantify (at least approximately) deviations from the responses expected from previous rigorous calibrations. On the basis of such an analysis, a given pressure transducer could be removed from service, rigorously recalibrated, or continued in use with corrections applied for calibration drift. The use of the health check could provide timely warnings of pressure-transducer malfunctions and make it possible to retain confidence in the calibrations of pressure transducers while reducing the frequency with which they

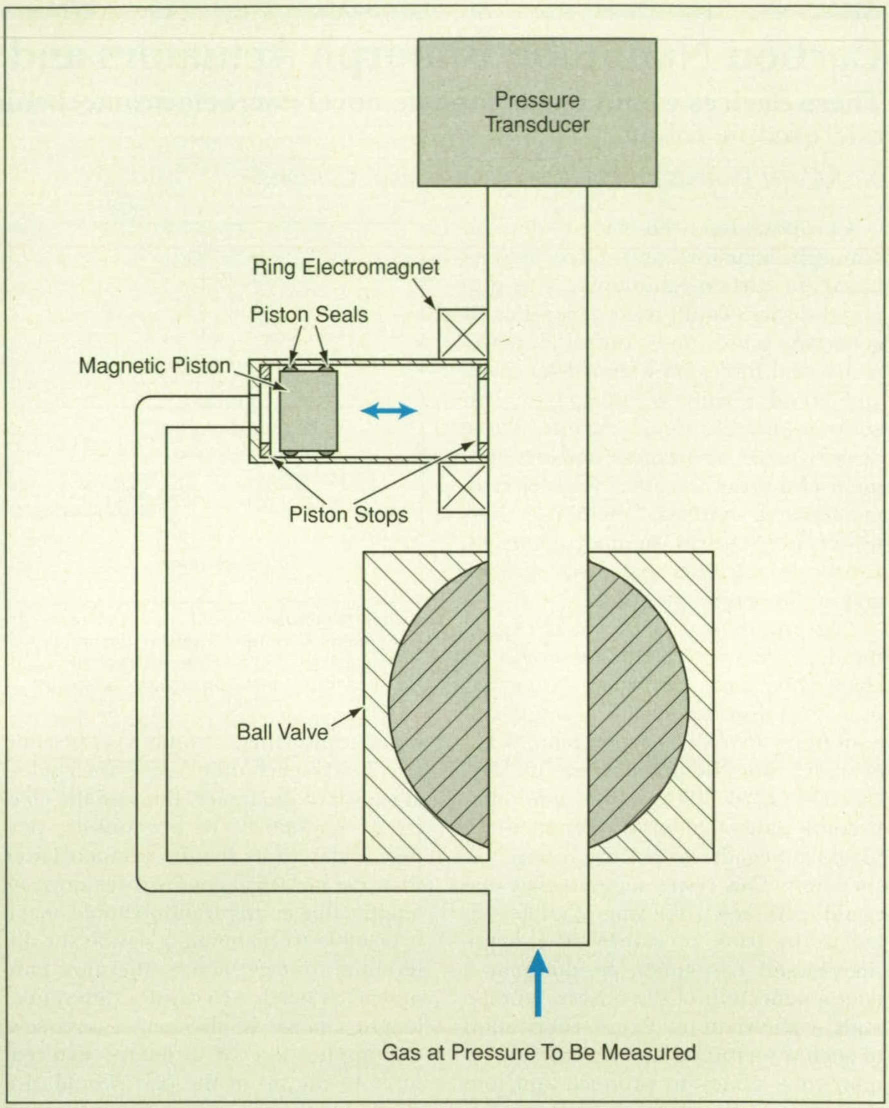

Figure 1. The **Volume of Gas** trapped between the piston and the ball valve would be known and would change by a known amount when the piston was actuated by the ring electromagnet.

are replaced or subjected to full laboratory recalibration.

A pressure-transducer health check would typically include (1) a circuit that would, on command, insert a shunt calibration resistor in a bridge circuit within which the pressure transducer normally functions, (2) a device that would compress or expand a known amount of trapped gas to effect an increase or decrease of input pressure, and (3) optionally, a gas-temperature transducer. The health check must be subjected to an initial rigorous calibration along with the pressure transducer.

During the operation of the health check, the change in the output voltage of the bridge circuit occasioned by the connection or disconnection of the shunt resistor would be measured and compared with the corresponding change in voltage measured during the rigorous calibration. Any difference between these voltage changes would be attributed to a change in sensitivity of the pressure transducer or, equivalently, in the amplification in its signal-processing circuitry.

Figure 1 depicts the compression/expansion portion of the health check device installed on the input tube of a typical pressure transducer. To perform a health check, first the pressure transducer would be exposed to ambient pressure, then a ball valve would be actuated to trap gas in the pressure transducer, then a piston would be actuated by an electromagnet to change the volume of the trapped gas. A first pressure-transducer reading would be taken before the piston stroke; a second pressure-transducer reading would be taken long enough after the stroke that any measurable transient heating from compression or transient cooling from rarefaction would have dissipated, but not so long after actuation that the ambient temperature would have changed. By use of Boyle's law, the actual pressure

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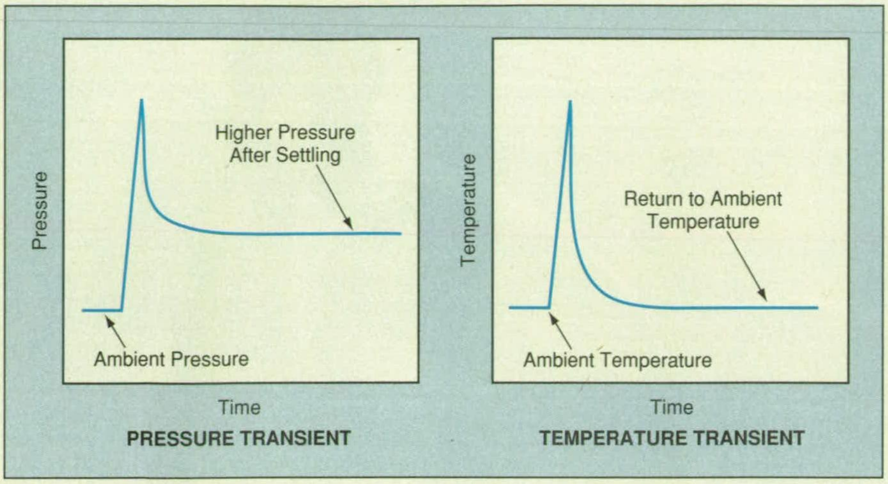


Figure 2. **Transient Decays of Pressure and Temperature** occur immediately after the compression stroke of the piston. The pressure settles to a steady higher value, while the temperature returns to the ambient value.

after the piston stroke could be calculated from the ambient pressure and the ratio between the volumes, which would have been determined in the rigorous calibration. Pressure-transducer readings taken over several cycles of exposure to ambient pressure, compression, and rarefaction could be analyzed to determine any deviations from calibration and to characterize the response of the pressure transducer with respect to repeatability, hysteresis, and linearity.

The inclusion of a gas-temperature transducer would make it possible to extract additional information from the decay of the temperature transient that follows the piston stroke (see Figure 2). One would measure the temperature at intervals much smaller than the characteristic time of the temperature transient and would then attempt to fit the measured temperatures to a decaying exponential.

The reason for attempting this fit is that to a first approximation, the temperature of the gas would decay exponentially toward the ambient temperature with a characteristic time

$$\tau = mc_v/hA,$$

where m is the mass of the trapped gas, c_v is the specific heat of the gas at constant volume, h is a heat-transfer coefficient, and A is the total area of all surfaces that enclose the trapped gas. The value of c_v is known and the values of h and A would be determined during the rigorous calibration. Fitting the temperature measurements to an exponential would provide the value of τ, from which one could calculate m.

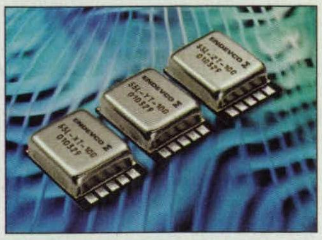
Using m, the known volume of the container, and the ideal-gas law or any other equation of state that is appropriate, one could calculate the pressure of the trapped gas as a function of temperature. This calculation would provide an additional calibration of the pressure transducer against the temperature transducer, making it possible to use the temperature transducer to perform an additional health check.

If either the pressure or the temperature transducer were malfunctioning and it could be determined which was malfunctioning, then by use of the ideal-gas law, one could still estimate the pressure or temperature from the temperature or pressure reading, respectively. As another health check, if either the temperature or the pressure measurements during the transient were to fit a decaying exponential poorly, then the temperature or pressure transducer, respectively, could be assumed to be responding nonlinearly and malfunctioning. As yet another health check, temperature and pressure readings could be compared through the equation of state to determine whether there was an offset error in the output of one of the transducers (though it would not be possible to determine which had the offset).

This work was done by Richard T. Deyoe, Pedro Medelius, Christopher Immer, Stanley Starr, and Anthony Eckhoff of Dynacs Engineering Co., Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-4879. Refer to KSC-12139/12077.

Special Coverage: Sensors



Endevco Corp., San Juan Capistrano, CA, has introduced the PiezoPAK series of **piezoelectric accelerometers** for integrated vibration measurement of machines, structures, and vehicles. The units offer wide frequency response, shock survivability, and low noise. Other features include shielding, ground isolation, and sealing against environmental contamination. Five solder pads are provided for power and signal connection.

The accelerometers offer 15 mV/g or 100 mV/g sensitivity with X, Y, or Z axis orientation. Signal ground is connected to the cover and an internal shield. An optional temperature sensor with a linear output of 10 mV/°C is available. The temperature sensor has a separate power input and requires a voltage of 4.5 to 10 VDC. At 0°C the unit has a 500 mV bias. The PiezoPAK series can be packaged into customized housings, allowing for cable/connector options.

For Free Info Circle No. 704 or Enter No. 704 at www.nasatech.com/rs

The S667 Thermal Tab™ **RTD temperature sensor** from Minco Products, Minneapolis, MN, is a rugged flat package sealed against moisture for wet environments or immersion in water. The sensor is suitable for OEM applications including temperature compensation in instruments, chiller and duct measurements in HVAC systems, environmental test chambers, and equipment or machinery exposed to moisture or wash-down.

The sensor can be mounted to flat or curved surfaces with epoxy or RTV cement. It has a silicone rubber insulated body and AWG 26 leadwires for installation. The unit is rated to 155°C and has a response time of less than two seconds. Standard elements include 100Ω and 1000Ω Platinum, and 100 Ω Nickel.

For Free Info Circle No. 701 or Enter No. 701 at www.nasatech.com/rs

Larson Davis, Provo, UT, offers the DSS™ **digital sensor system** integrating high-resolution, 24-bit analog/digital converters and sensors in a multi-drop broadband network, simplifying the overall cabling requirements for high-channel-count testing. The system receiver provides system power, signal demodulation, time data storage, and PC interface for up to 64 channels. Each channel is composed of a sensor and a compatible Dynamic Sensor Interface Transceiver (DSIT™), which handles sensor-specific signal conditioning, application-specific ACD range, and signal modulation.

More than 16 sensors can communicate on a single cable, and a variety of sensors and sampling rates can operate on the same ribbon cable. Applications include distributed time data recording for automotive NVH, civil infrastructure vibration monitoring, and industrial monitoring/predictive maintenance of mills.

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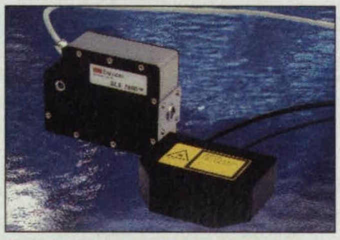

LMI Electronics, Detroit, MI, has introduced the Class II LMI Selcom SLS 7000 Specular Reflective Sensor, a non-contact laser-based industrial **gauging sensor** with a 250-nm resolution range over a 1-mm measurement range. The sensor uses specular reflective triangulation measurement techniques to measure surfaces such as mirrors, silicon wafers, and other reflective materials. The sensor has a 16-kHz sample rate and features a 10- to 20-micron visible laser spot that enables profiling of intricate target structures such as miniscule cracks and groves.

The unit features a built-in digital processor for data averaging and filtering that is contained in a separate controller unit that interfaces with the sensor head. An internal feedback loop automatically compensates for differences in detected light intensity due to the object's color and texture by varying power to the laser diode. An optional CCD camera is available for micropositioning the laser on a target.

For Free Info Circle No. 703 or Enter No. 703 at www.nasatech.com/rs

Cognex Corp., Natick, MA, has released the In-Sight 1000C self-contained **machine vision sensor** featuring vision software tools designed for color image processing and analysis. The sensor verifies and sorts parts based on their color. Used with a color monitor, it displays color inspection images, allowing operators to monitor parts locally and remotely. The sensor can be added to any point on a production line where color part-checking is needed, and can communicate with other In-Sight sensors over Ethernet.

The sensor combines image processing hardware, software, and communications in a rugged package. It can be integrated with PC-based factory automation devices via Ethernet, and with PLCs on the factory floor via DeviceNet, ModBus, and ProfiBus communications. Accessories include LED-based lighting modules, an Ethernet panel PC monitor, a DeviceNet interface module, expansion I/O, cables, and lens kits.

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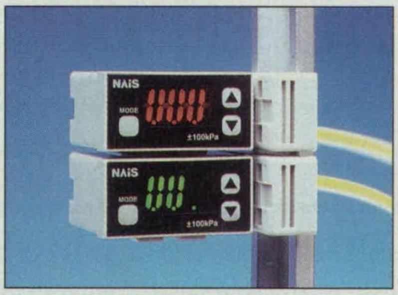


The UZU3 series dual-color **digital pressure sensor** from Aromat Corp., New Providence, NJ, features a two-color panel that displays both in digital and analog bar mode, and functions as an output indicator, switching display color between green and red. The minimum required cutout of the equipment panel is 0.669 × 1.452". Features include DIN rail mounting in four different orientations and snap-fit connection for cable connection. For multiple unit mounting, no space is required between the two units.

The sensor provides a response time of 2 ms or less and is capable of sensing vacuum and/or positive pressure ranging from -14.7 psi to 152.2 psi (from -100kPa to 1.000MPa). The unit weighs 1.062 ounces without the cables.

For Free Info Circle No. 705 or Enter No. 705 at www.nasatech.com/rs

Improvements in a Fast Transient-Voltage Recorder

The instrument is now more readily adjustable and reconfigurable.

John F. Kennedy Space Center, Florida

Some improvements have been made in an instrument designed expressly for recording lightning-induced transient voltages on power and signal cables. The instrument as it existed prior to the improvements was described in "Fast Transient-Voltage Recorder" (KSC-11991), *NASA Tech Briefs*, Vol. 23, No. 10 (October 1999), page 6a.

The prior version of the instrument could sample transient voltages in four channels at a rate of 20 megasamples per second (MS/s). In the improved version, the rate can be easily increased to 100 MS/s. The prior version of the instrument could handle a peak input potential of 50 V, or more if an attenuator was used. The improved version accommodates typical input ranges of 10, 50, and 100 V. The input termination can be single-ended or differential, with input resistance selectable among 50 Ω, 120 Ω, or 10 kΩ.

A trigger circuit continuously monitors the signals on all four channels, comparing the signal level on each channel with a predetermined threshold level. The threshold for each channel in the original version could be set at any level from 5 to 95 percent of full scale, independently of the threshold levels for the other channels; in the improved version, threshold can be set at any level between 1 and 99 percent. When the signal level in any channel exceeds its threshold level, a trigger signal is generated, causing full recording of data to begin simultaneously on all four channels.

Even when data are not being recorded fully, 12-bit analog-to-digital (A/D) converters in the four channels operate continuously, temporarily storing their output data in first-in/first-out (FIFO) registers that are always kept half full. When a trigger signal is received, the remaining halves of the FIFO registers are filled up with data. Inasmuch as the full capacity of each FIFO register corresponds to an observation interval of 200 μs, this arrangement provides a 100-μs pretrigger recording capability.

In the previous version, once a transient had been thus recorded, and during intervals of inactivity, the data were transferred to a nonvolatile memory. In the improved version, the data are transferred to both the nonvolatile memory and a second set of FIFO registers. The second FIFO set can be made as deep as needed to store as many waveforms as required. The design of the improved version makes it easy to replace either or both sets of FIFO registers to change record lengths and waveform-storage capacities. The nonvolatile memory retains the data even if power is lost.

The previous version of the instrument was equipped with a clock, and the stored data were time-coded to establish the times of transients and to facilitate correlation with data on the same transients measured by other instruments. The improved version retains this internal clock, but is also equipped with a Global Positioning System (GPS) receiver and an Inter Range Instrumentation Group B (IRIG-B) decoder for accurate time stamping of any recorded waveform. If the IRIG-B signal is lost, the waveform is stamped with the time from the internal clock.

Like the previous version of the instrument, the present version is normally powered through an ordinary AC power line and includes backup batteries. During normal operation, the batteries are automatically charged. In the event of failure of AC power, the batteries can sustain operation for as long as 8 hours.

The design of the improved version is amenable to the addition of a cellular-telephone data link or other radio transceiver to enable remote interrogation of the status of the transient recorder or to retrieve data either on request or at scheduled intervals. For applications in which real-time retrieval of data is not feasible, one could use such other data-storage devices as rewriteable compact-disk read-only memories (CD-ROMs). The introduction of CD-ROMs would increase the data-acquisition and -storage capacity from the current level of 16 waveforms to several tens of thousands of waveforms.

This work was done by Pedro J. Medelius of Dynacs Engineering Co., Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.* *KSC-12174*

Improved Field-Emission Cathodes

Arrays of microscopic cathodes would resist poisoning and sputtering.

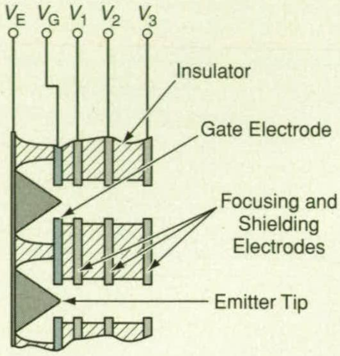
NASA's Jet Propulsion Laboratory, Pasadena, California

Microscopic cathodes based on field emission (in contradistinction to thermionic emission) are undergoing development with a view toward using them as miniature or scalable sources of electrons in diverse applications that could include spacecraft thrusters, semiconductor-fabrication equipment, flat-panel display devices, miniature x-ray sources, and electrodynamic tethers and mass spectrometers. Increasing current levels can be accomplished by increasing the number of tips in an array. The basic concepts of utilizing field-emission cathodes for such applications and of scaling up by enlarging arrays are not new; the novel aspect of the present developmental cold cathodes lies in a microfabricated cathode lens and ion repeller (CLAIR) similar to an Einzel lens which will enable the

integration of field-emission cathodes with electric propulsion systems, electrodynamic tethers, and instruments while meeting performance and lifetime requirements.

The performance requirements include emitter currents in the milliampere range at gate-electrode potentials between 10 and 70 V, high efficiency, and ability of emitter tips to strongly resist sputtering by impinging ions. More specifically:

- Gate potentials are required to be low in order to minimize the kinetic energies of ions bombarding emitter tips.
- In some applications, electron energies >20 eV are required to increase the space-charge current limit in plasma environments.
- For efficiency, leakage currents through gate electrodes must be kept to small fractions of emitted currents; it should not be difficult to satisfy this requirement in that gate leakage current is typically as little as a thousandth of the emitted current.
- The ability of an emitter tip to resist sputtering and poisoning with oxygen depends largely on the emitter material. It is desirable to choose an emitter material which is stable in an oxygen-rich environment, is not easily sputtered away when bombarded with ions, and has a low work function. Several materials are under investigation to meet these demands.



Potential, Volts				
V_E	V_G	V_1	V_2	V_3
−40	10	−10	100	−20

Dimensions, µm					
$d_{G,1}$	$d_{1,2}$	$d_{2,3}$	t_1 & t_3	t_2	ϕ
0.4	0.8	0.8	0.1	0.3	1.2

Side-by-Side Field-Emission Cathodes would be configured and operated to independently control electron energy and electron current density.

The figure depicts (not to scale) the configuration of an array of field-emission cathodes with CLAIR. Typical electrode thicknesses (t_i), interelectrode distances (d_i), aperture diameter (ϕ), and operating potentials (V_i) are shown according to one of the design concepts. Acting in concert, the V_1, V_2, and V_3 electrodes would accelerate or decelerate and focus the emitted electron beam. Singly-charged ions entering the cathode with kinetic energies below 65 eV would be retarded by the electric field between V_2 and V_3. In the case of a spacecraft thruster, the V_3 electrode would also shield the ion-retarding electrodes from electrons in the thruster discharge. The CLAIR configuration without the field emission tips can be used as an ion energy analyzer in plasma environments.

This work was done by Colleen Marrese of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-21043

LabVIEW as Flight Software With VxWorks Operating System

A development effort under way at the time of reporting the information for this article is directed toward producing a version of the LabVIEW data-acquisition software that would be suitable for use as flight software that could be executed in the VxWorks real-time operating system. The approach taken in this effort is to utilize the graphical programming capability of the LabVIEW software system to reduce the time and cost of developing flight software and, more specifically, to make it possible for ground-based software to be transferred to and utilized in a flight environment without rewriting the software. Thus far, a prototype flight version of LabVIEW has been developed to run in a VxWorks real-time operating system on an embedded processor for precisely controlling the temperature of an isolated cryogenic platform. (The temperature-control system is undergoing development for use in a future low-temperature microgravitational facility.)

This program was written by Edmund Baroth, Hyung Cho, Martin Barmatz, Phillip Yates, and Phillip Withington of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21124.

MPP Port of PVM to a Beowulf Computer System

The latest version of the Parallel Virtual Machine (PVM) computer program, denoted PVM 3.4.3, incorporates a massively-parallel-processor (MPP) software port that enables a user working on a computer outside a Beowulf system (a cluster of personal computers that run the Linux operating system) to incorporate the Beowulf system, as though it were a single computer, into the larger parallel machine administered by PVM. One of the big advantages of PVM is its ability to easily tie together heterogeneous computing systems. However, up to now, there has been no way to spawn a PVM task from outside a Beowulf system onto one of the nodes of the cluster if the node lacks an externally visible Internet Protocol (IP) address. The Beowulf/Linux port of PVM 3.4.3, denoted BEOLIN, was incorporated to overcome this limitation. The user need only add the externally visible address of the cluster host (one of the computers in the cluster that acts as a "front end" for communication between outside computers and the computers in the cluster). Thereafter, the BEOLIN code automatically assigns tasks to individual nodes within the cluster while hiding the details of the cluster from the user.

This program was written by Paul Springer of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category. PVM 3.4.3 is available for download from http://www.epm.ornl.gov/pvm/.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21048.

Software for Iterative Optimization of Plans

The Iterative Plan Optimization computer program automatically optimizes plans with respect to preferences expressed by human planners. This program incorporates a generalization of commonly occurring plan-quality metrics to provide a language for expression of preferences. The program implements a technique of iterative optimization that is a generalization of a prior technique of iterative repair, in which conflicts are detected and addressed one at a time until either no conflicts exist or a user-defined time limit has been exceeded. During iterative optimization, low-scoring preferences are detected and addressed individually until the maximum score is attained or until a user-defined time limit has been exceeded. A preference is a quality metric for a plan variable and can be improved by modifying the plan in a manner similar to that of repairing it. Plan modifications can include moving, creating, and deleting activities. For each preference, a domain-independent improvement-expert subprogram automatically generates the subset of modifications that could potentially improve the preference score.

This program was written by Steve Chien, Barbara Engelhardt, and Gregg Rabideau of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20922.

Software for Planning an SAR Antarctic Mapping Mission

The AMM Automated Mission Planner computer program was developed to save time and money by automating much of the planning of the Second RADARSAT Antarctic Mapping Mission (AMM), which was scheduled to take place at the time of writing this article. The planning problem for this and other RADARSAT missions is to select several hundred synthetic-aperture-radar (SAR) swaths that satisfy scientific objectives, which include coverage of a specified ground area. The selection is subject to constraints associated with the choice of downlink opportunities and with RADARSAT operation. These constraints interact in complex ways that make it difficult to design schedules manually. The software takes a set of SAR swaths and automatically generates a locally optimal downlink schedule and identifies violations of operational constraints; in so doing, the software frees the mission planner to concentrate on selecting swaths that satisfy scientific objectives. Mission-planning time has thus been reduced from years to weeks.

This program was written by Barbara Engelhardt, Steve Chien, Russell Knight, Benjamin Smith, Darren Mutz, Robert Sherwood, Gregg Rabideau, and John Crawford of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21092.

Predicting Stresses in Thermal-Barrier Coatings

Creep, oxidation, differential thermal expansion, and interface roughness are taken into account.

John H. Glenn Research Center, Cleveland, Ohio

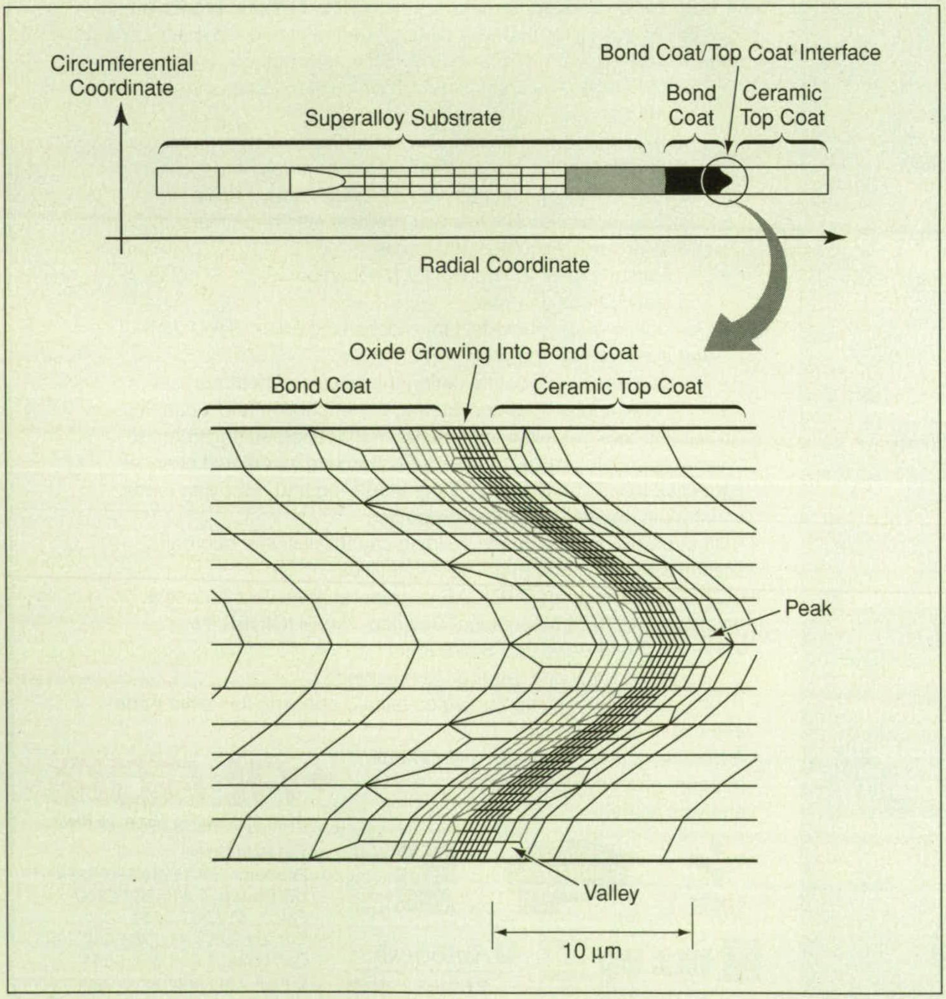
A methodology for predicting stresses and the resultant cracking in plasma-sprayed thermal-barrier coatings (TBCs) has been developed. The methodology is built around a computer code that implements a finite-element model that simulates the evolution of stresses, strains, and related phenomena in a TBC. The economic and technological value of the methodology lies in its potential to provide a more systematic basis for designing reliable and durable TBCs for advanced gas turbine engines by reducing the amount of time-consuming empirical testing needed to assess alternative TBC designs.

A TBC typically comprises a ceramic top coat deposited on an alloy bond coat that has been deposited on a superalloy substrate that the TBC is intended to protect. Together, the TBC and the substrate constitute a complex material system. Finite-element modeling is necessary to predict the complex, interactive thermomechanical and chemical behaviors of the component material layers.

The present finite-element model is capable of making such predictions over a range of conditions to which TBCs are exposed during operation of engines and during thermal cycling in burner test rigs. Originally developed within the framework of the Lawrence Livermore National Laboratory code NIKE2D, the model has recently been implemented into a new framework using the commercial FEA code ABAQUS™, a product of Hibbitt, Karlsson & Sorensen, Inc. Variable phenomena that are represented in the model include transient thermal behavior, multiple thermal cycles, and oxidation of the bond coat. The initiation of fractures and the propagation of cracks are represented by a stress-based crack-initiation criterion and a fracture-mechanics submodel. The creep behavior of each constituent material is represented by a temperature-dependent power-law creep submodel.

Oxidation of the bond coat is represented by use of provisions within the codes that allow for the transformation of constituent materials. The bond-coat oxide starts at the bond-coat/top-coat interface and grows into the thickness of the bond coat. In the model, on the basis of empirical data on the rate of growth of an oxide layer on a bond-coat material, bond-coat-alloy finite elements are replaced by bond-coat-oxide finite elements at fixed intervals of time, starting at the bond-coat/top-coat interface.

The model can be used to assess the effects of numerous material, process, or geometric variables on the stress behavior within a TBC. Five principal variables originally studied and characterized during model development were oxidation, bond-coat creep, top-coat creep, bond-coat thermal expansion, and interfacial roughness. The outputs of the model include stresses as functions of time, location, and direction. The model has been applied to a burner-rig speci-



This **Small Part of the Finite-Element Model** shows the geometric relationships of the various layers and the simulation of surface roughness by use of a sinusoidal waviness.

men, which is a 25.4-mm-diameter rod of Waspalloy (or equivalent superalloy) with a side TBC composed of 0.13-mm-thick NiCrAlY bond coat and a 0.25-mm-thick top coat comprised of a mixture of zirconia with 8 weight percent yttria. To simulate the effect of surface roughness of a typical TBC, the radial coordinate of the bond-coat/top-coat interface was made to vary as a sinusoidal function of the circumferential coordinate, with a peak-to-valley amplitude of 10 μm (see figure).

The numerical results of the application have been interpreted as signifying that oxidation of the bond coat exerts a strong effect on stresses in the ceramic layer and that stresses induced by oxidation are influenced by other factors, including bond-coat creep, top-coat creep and bond-coat roughness. It was also concluded that the progression of cracking is a result of the combined action of creep, oxidation, and thermal cycling. An accurate description of the entire process requires a model including these factors. It was further concluded that as complex as the model is, it is still too simple to provide a complete description of the failure of a TBC, and that for greater accuracy, it would be necessary to account for such other factors as (1) sintering phase changes in the oxide, bond coat, and ceramic layers and (2) cracking and changes in composition in the ceramic layer.

This work was done by Andrew Freborg and B. Lynn Ferguson of Deformation Control Technology, Inc., for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16783.

Enhancing the Removal of Chlorocarbons From Groundwater

Sonication apparently removes corrosion products that inhibit dechlorination.

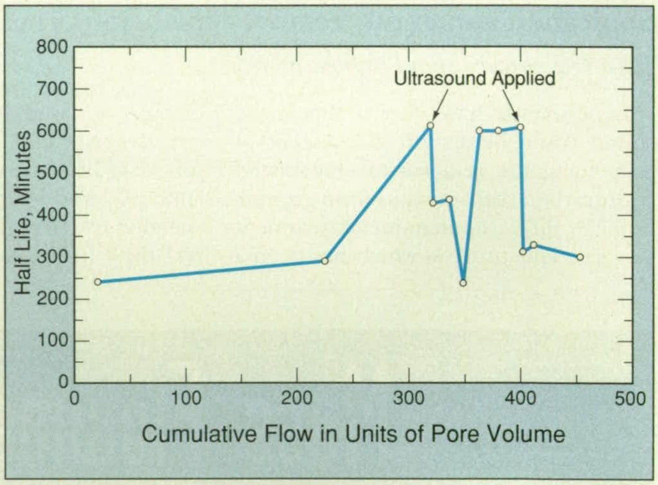
John F. Kennedy Space Center, Florida

Experiments have shown that ultrasound could be an effective means of enhancing the removal of chlorinated hydrocarbon contaminants from groundwater by the zero-valent-metal treatment process. This process, which has been a subject of research in recent years, is attractive because it does not involve above-ground treatment or the use of pumps, and because the materials needed to effect treatment are safe and relatively inexpensive.

The process involves the use of a permeable wall that contains a metal (iron or zinc) in zero-valent condition and in porous form (e.g., dust or filings) and is buried in the ground. The position and orientation of the wall are chosen to take advantage of the natural groundwater gradient to carry the groundwater through the wall. As the contaminated groundwater flows through the wall, chlorine is removed from chlorinated hydrocarbons and from breakdown byproducts. The dechlorination reaction mechanism, which is not known precisely, appears to involve the simultaneous oxidation of metal and dechlorination of chlorinated hydrocarbons. For example, the removal of trichloroethane by treatment with iron appears to include the reactions:

$Fe^0 \rightarrow Fe^{2+} + 2e^-$ and $C_2HCl_3 + 3H^+ + 6e^- \rightarrow C_2H_4 + 3Cl^-$.

Thus, the destruction of one mole of trichloroethane yields three moles of chloride and results in an increase in pH because of the consumption of protons. In addition, corrosion of iron is inherently part of the electron-transfer process that drives the dechlorination. The rate of dechlorination by a treatment wall decreases with time, apparently because the precipitation of corrosion products reduces the iron surface area accessible for dechlorination. In some cases, the rate of dechlorination could be reduced further because accumulation of corrosion products in pores could reduce the permeability of the wall.



The **Half Life of Trichloroethane** in water flowing through a column filled with 50-mesh iron initially increased with time; that is, the column performance deteriorated. The subsequent application of ultrasound on two occasions caused sharp decreases in half life; that is, sonication restored column performance.

The foregoing observations lead to the concept of using ultrasound to enhance treatment. It has been postulated that ultrasound can be used to remove corrosion products from iron surfaces and therefore can be used to restore and maintain rates of dechlorination. Results of batch and column-flow experiments confirm that exposure to ultrasound increases dechlorination rates significantly (see figure). Further experimental studies would be needed to develop a full-scale, practical ultrasonic system to enhance the function of a full-scale treatment wall.

This work was done by Jacqueline Quinn of **Kennedy Space Center** *and Nancy E. Ruiz, Debra R. Reinhart, Cherie L. Geiger, and Christian A. Clausen III of the University of Central Florida. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-6373. Refer to KSC-11959.

Magnetic/Extendible Boom Mechanism for Docking of Spacecraft

Docking loads can be smaller than those of prior mechanisms.

Lyndon B. Johnson Space Center, Houston, Texas

The magnetic/extendible boom docking aid is an improved mechanism that enables two spacecraft to capture and structurally mate with each other without inducing the large (and frequently excessive) loads encountered in docking by use of prior docking mechanisms. The capability afforded by this mechanism should prove invaluable when applied to the International Space Station. This mechanism is relatively simple to construct, easily integrable into pre-existing docking hardware, and highly reliable.

The magnetic/extendible boom docking aid (see Figure 1) includes an assembly that contains a powered extendible boom with an electromagnet attached to the end; this assembly is mounted on one of two spacecraft that are to dock with each other. A target plate is affixed to the other spacecraft in the mating position. There can be as many points of contact and corresponding magnetic/extendible boom docking aids as are needed to effect safe and efficient docking. When the two spacecraft have moved into docking approach position, the booms are extended and the electromagnets are switched on. The

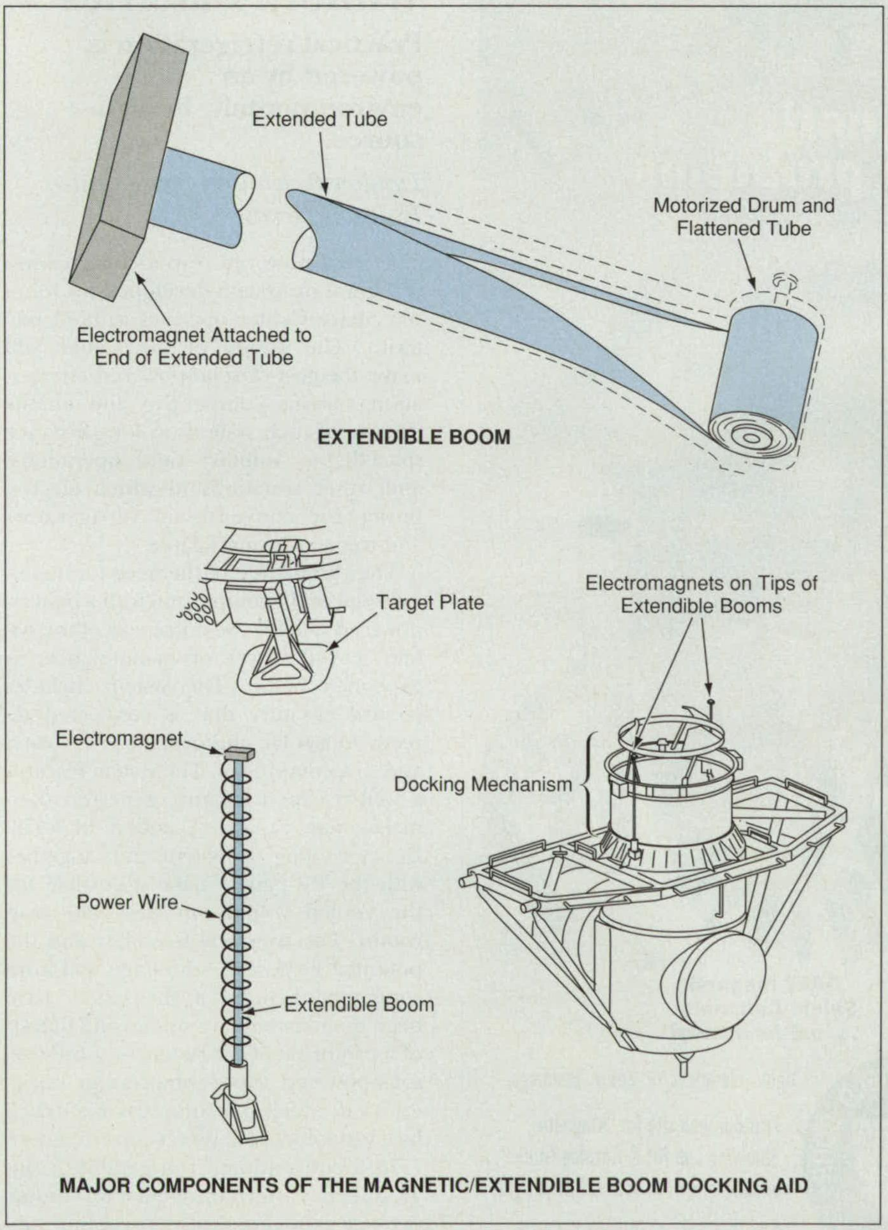


Figure 1. The **Boom Is Extended** by unrolling a flattened tube from a motorized drum. The boom is flexible in torsion and bending, stiff in tension, and back-driven in compression. The electromagnet on the tip of the boom attracts a target plate on the mating spacecraft.

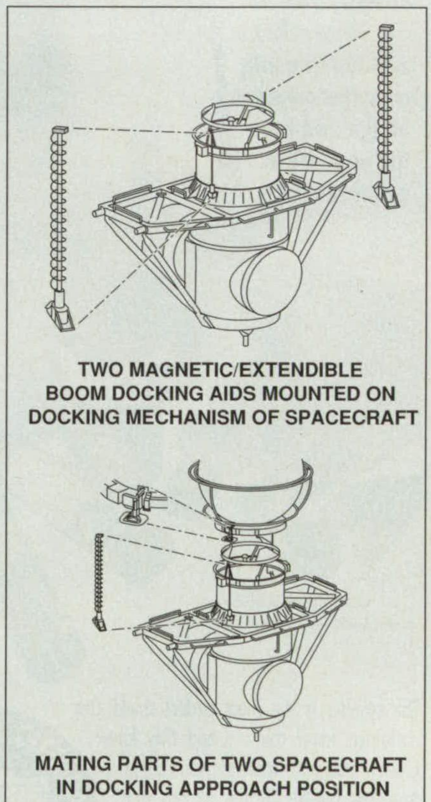


Figure 2. **Mating Parts of Two Spacecraft** approach each other very slowly until the electromagnets on the extendible booms of one spacecraft magnetically attract the target plates of the other spacecraft. Then the booms are retracted slowly to complete docking.

spacecraft are made to approach each other very slowly until the electromagnets make contact with, and become magnetically attached to, the target plates (see Figure 2). The spacecraft are slowly drawn together by withdrawing the booms until docking-mechanism latches are actuated. Mating is considered to have been achieved once the latches have been fully actuated.

Heretofore, two large spacecraft have been docked by causing the spacecraft to approach each other at a speed sufficient to activate capture latches — a procedure that results in large docking loads and is made more difficult because of the speed. The basic design and mode of operation of the magnetic/extendible boom eliminates the need to rely on speed of approach to activate capture latches, thereby making it possible to reduce approach speed and thus docking loads substantially.

Magnetic/extendible boom docking aids could be used on space-station modules and on proposed lunar transfer spacecraft. They could also be used in the construction and operation of underwater habitat modules. Ultimately, they may even be useful in robotic operation of submersible vessels used to drill for oil. However, the commercial market may be limited because most land-based processes and equipment can withstand the high contact loads of conventional docking.

This work was done by William C. Schneider, Kornel Nagy, and John P. McManamen of **Johnson Space Center**. *For further information, contact the Johnson Space Center Commercial Technology Office at (281) 483-0474.*
MSC-22750

Vapor-Compression Solar Refrigerator Without Batteries

Practical refrigeration is powered by an environmentally benign source.

Lyndon B. Johnson Space Center, Houston, Texas

A solar-powered vapor-compression refrigeration system developed for Johnson Space Center operates without batteries. The design of this system will make the cost of solar-powered refrigeration systems competitive and enable the use of such systems in long-distance spaceflights, military field operations, and other situations in which electric power for conventional refrigerators and freezers is unavailable.

The elimination of the need for batteries reduces (in comparison with a battery-powered system) the initial cost of the system and the cost of maintenance, as explained below. The system includes control circuitry that is connected directly to a solar photovoltaic (PV) panel and to a compressor. The system features a well-insulated cabinet, generous thermal-storage capability, and a high-efficiency cooling subsystem, that, together with the PV panel, make it possible for the cooled volume to stay cold year-round. The technical feasibility and the potential economic advantage and environmental benefit of the system have been demonstrated in studies and in tests of a prototype of the system — a full-size, solar-powered vapor-compression refrigerator in which the compressor is driven by a variable-speed, direct-current motor.

In a conventional refrigerator, a single-speed, alternating-current motor drives a vapor-compression cooling subsystem housed in a moderately insulated cabinet. Unfortunately, because a conventional refrigerator is designed to rely on an electric-power grid, its utility is restricted in spaceflight, military applications, or wherever electricity is unavailable or expensive. Prior solar-powered refrigerators included large batteries that were recharged by PV panels, or else thermal-cycle heat pumps rated at efficiencies lower than those of vapor-compression systems. Although the use of solar energy is environmentally benign, its widespread application has been slowed by a lack of cost-effective means. Where solar energy systems have been tried, they have lowered overhead, but because of the need for batteries and/or dc-to-ac power conversion, they have not eliminated it altogether. The present system eliminates the weights and costs of batteries and dc-to-ac power conversion subsystems.

The present system concept is flexible and allows variations of the basic design. The size of the cabinet can be chosen, with appropriate matching of the cooler, thermal-store, and PV capacities. In an alternative version of the system, one could reduce or eliminate thermal storage and incorporate electronic controls that would utilize backup power from a power grid or other source; this version could be cost-effective in an urban setting as well as in a remote setting. The scope of potential commercial applications could be widened by extending the concept to solar-powered freezers, ice makers, and air conditioners.

This work was done by Michael K. Ewert of **Johnson Space Center** *and David J. Bergeron III of Space Industries, a Division of GB Tech, Inc.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22970.

Variable-Specific-Impulse Magnetoplasma Rocket

This rocket is expected to enable long-term human exploration of outer space.

Lyndon B. Johnson Space Center, Houston, Texas

Johnson Space Center has been leading the development of a high-power, electrothermal plasma rocket — the variable-specific-impulse magnetoplasma rocket (VASIMR) — that is capable of exhaust modulation at constant power. An electrodeless design enables the rocket to operate at power densities much greater than those of more conventional magnetoplasma or ion engines. An aspect of the engine design that affords a capability to achieve both high and variable specific impulse (I_{sp}) places the VASIMR far ahead of anything available today. Inasmuch as this rocket can utilize hydrogen as its propellant, it can be operated at relatively low cost.

The design of the VASIMR is so original that a prototype is being developed in collaboration with the Department of Energy and with the Oak Ridge National Laboratory and its Center for Manufacturing Technology. The VASIMR is expected to be commercially useful for boosting communication satellites and other Earth-orbiting spacecraft to higher orbits, retrieving and servicing spacecraft in high orbits around the Earth, and boosting high-payload robotic spacecraft on very fast missions to other planets. Similarly, the VASIMR should make it possible for robotic spacecraft to travel quickly to the outer reaches of the Solar system and begin probing interstellar space. By far, the greatest potential of the VASIMR is expected to lie in its ability to significantly reduce the trip times for human missions to Mars and beyond. This reduction in times is expected to enable long-term exploration of outer space by humans — something that conventional rocket designs now preclude.

Because the VASIMR uses plasma to produce thrust, it is related to several previously developed thrusters; namely, the ion engine, the stationary plasma thruster (SPT) (also known as the Hall thruster), and the magnetoplasmadynamic (MPD) thruster [also known as the Lorentz-force accelerator (LFA)]. However, the VASIMR differs considerably from these other thrusters in that it lacks electrodes (a lack that enables the VASIMR to operate at much greater power densities) and has an inherent capability to achieve high and variable I_{sp}. Both the ion engine and the SPT are electrostatic in nature and can only accelerate ions present in plasmas by means of either (1) externally applied electric fields (i.e., applied by an external grid as on an ion engine) or (2) axial charge nonuniformity as in the SPT. These ion-acceleration features, in turn, result in accelerated exhaust beams that must be neutralized by electron sources strategically located at the outlets before the exhaust streams leave the engines.

In the LFA, acceleration is not electrostatic but electromagnetic. A radial electric current flowing from a central cathode interacts with a self-generated azimuthal magnetic field to produce acceleration. Although LFAs can operate at power levels higher than those of either the ion engine or the SPT and do not require charge neutralization, their performances are still limited by the erosion of their electrodes.

An MPD plasma injector includes a cathode in contact with the plasma. Although the plasma at the location of contact is relatively cold, the cathode becomes eroded and the plasma becomes contaminated with cathode material (typically tungsten). The erosion and contamination can contribute to premature failure and to increased loss of energy through radiation from the contaminants in the plasma. An equal limitation on performance is exerted by nonionized propellant in a high-power amplifier cavity that is part of the MPD; the reason for this limitation is that neutral atoms and molecules in this region lead to charge-exchange losses, which, in turn reduce the overall efficiency of the engine and increase the unwanted heat load on the first wall (the liner) of the MPD thruster.

The design of the VASIMR avoids the aforementioned limiting features. The VASIMR contains three major magnetic cells — the forward, central, and aft cells. A plasma is injected into these cells, then heated, then expanded in a magnetic nozzle. (The magnetic configuration is of a type known as an asymmetric mirror.) The forward cell handles the main injection of propellant gas and an ionization system; the central cell serves as an amplifier to further heat the plasma to desired magnetic-nozzle-input conditions; and the aft cell acts as a hybrid two-stage magnetic nozzle that converts the thermal energy of the fluid into directed flow while protecting the nozzle walls and allowing efficient detachment of the plasma from the magnetic field. During operation of the VASIMR, a neutral gas (typically, hydrogen) is injected into the forward cell, where it is ionized. The resulting plasma is then heated in the central cell, to the desired temperature and density, by use of radiofrequency excitation and ion cyclotron resonance. Once heated, the plasma is magnetically and gas-dynamically exhausted by the aft cell to provide modulated thrust. Contamination is virtually eliminated and premature failures of components are unlikely.

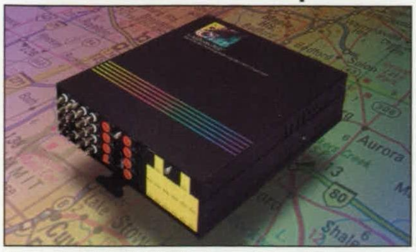
The VASIMR offers numerous advantages over the prior art:

- Its unique electrodeless design provides not only high thrust at maximum power but also highly efficient ion-cyclotron-resonance heating, and high efficiency of the VASIMR regarded as a helicon plasma source.
- Because the VASIMR operates at relatively high voltage and low current, its mass is relatively low. This means that a one-ship human mission will not depend on a high-energy, complex rendezvous near Earth to achieve escape velocity. Instead, a rapid interplanetary transfer will be achieved with an adaptable exhaust, which will provide optimal acceleration throughout the mission.
- The residual magnetic field of the engine and the hydrogen propellant will be effective as a shield against radiation.
- Because of its continuous acceleration, the VASIMR will be able to produce a small amount of artificial gravitation, thereby reducing the physiological deconditioning produced by weightlessness.
- The variability of thrust and I_{sp} at constant power will afford a wide range of capabilities to abort.
- Because hydrogen is the most abundant element in the universe, the supply of hydrogen could likely be regenerated *in situ*.
- The VASIMR is flexible and adaptable to both fast transfers of humans and slower high-payload robotic missions; hence, there would be no need to develop separate propulsion systems for missions of each type, and costs would be held down accordingly.
- Long-range benefits could be derived from the continued development of the VASIMR. The VASIMR can be expected to pave the way for fusion-driven plasma rockets. In addition, because the VASIMR is a high-I_{sp} rocket, the VASIMR concept can be expected to lead to lower initial mass in low Earth orbit, relative to nuclear, thermal, and/or chemical rockets.

This work was done by Franklin R. Chang-Díaz of **Johnson Space Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-23041.

Stand Alone Data Acquisition



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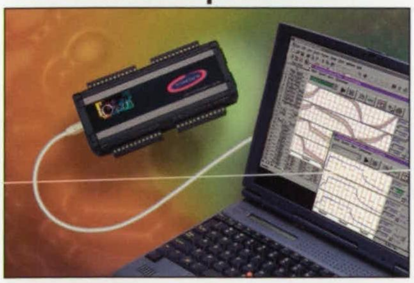

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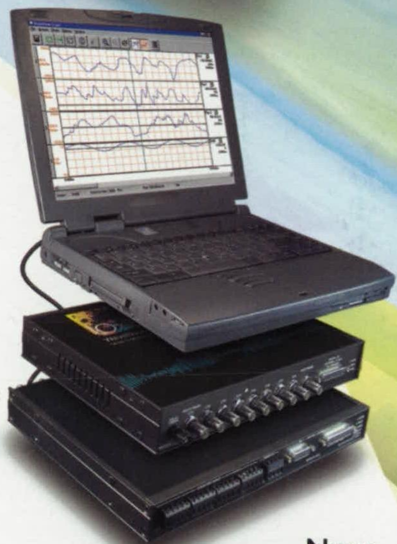

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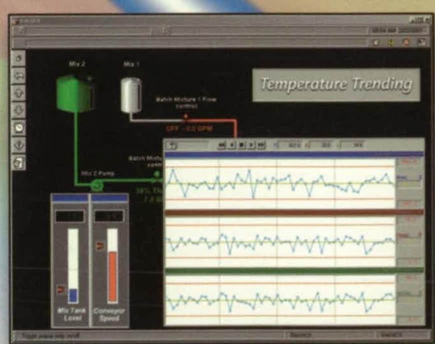

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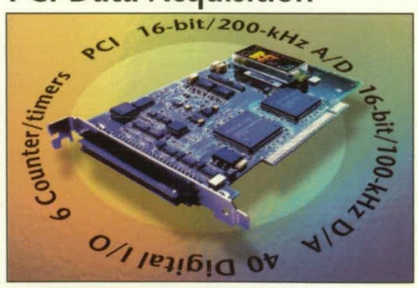
PCI Data Acquisition



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September 2001

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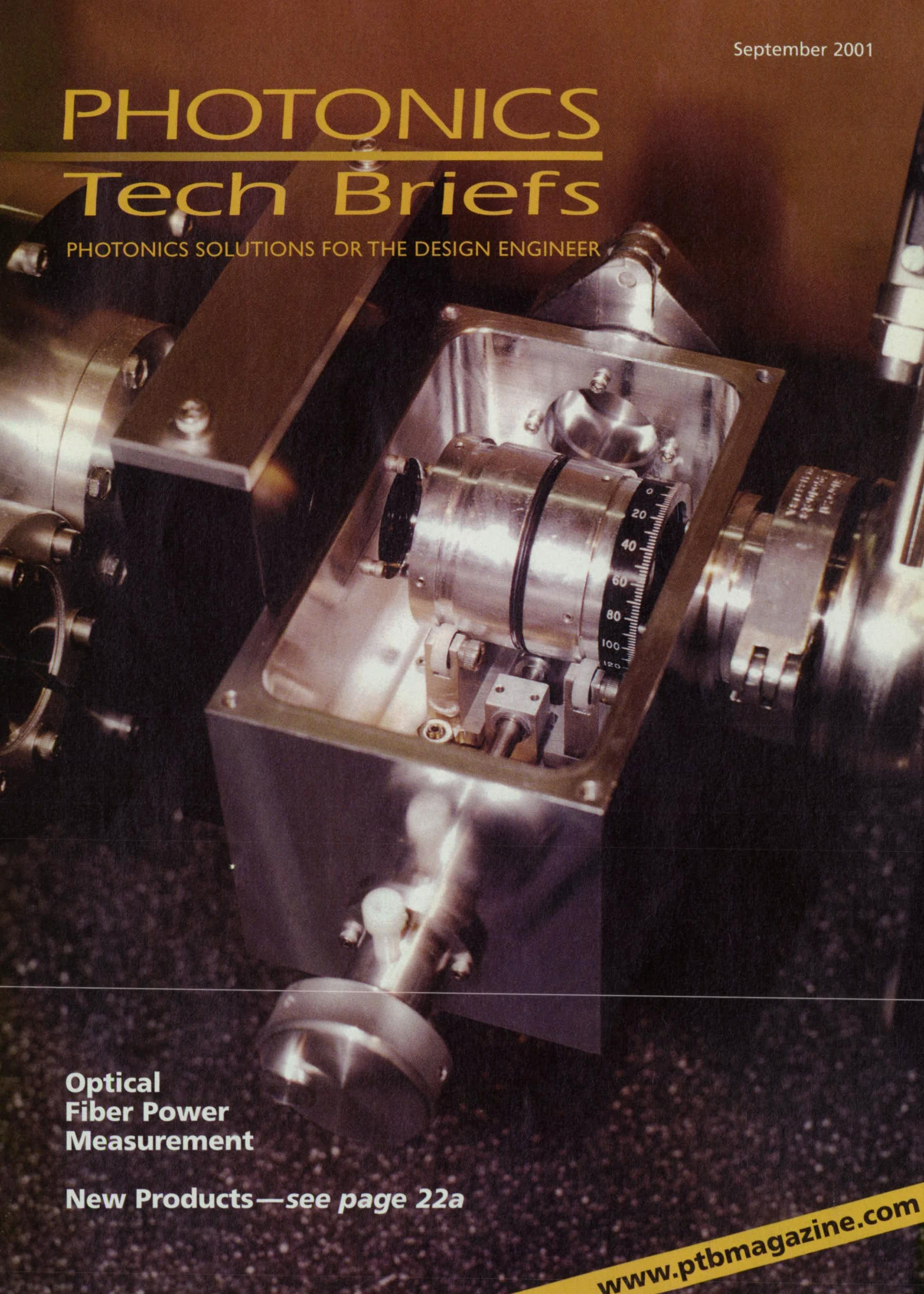

Optical Fiber Power Measurement

New Products—*see page 22a*

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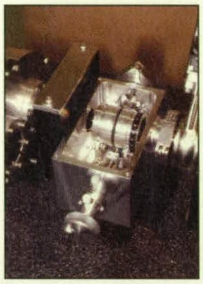

On the cover: *McPherson's vacuum-type polarizer/analyzer unit. Photo courtesy of McPherson Inc.*

Getting the Best Optical Power Measurements

National Instruments provides hardware and software tools that enhance results and cut costs.

Over the last few years, the demand for optical networks has exploded. An increasing number of communications manufacturers are designing products to leverage the high bandwidth and smaller size offered by optical components over their copper counterparts. In fact, some industry experts project that the optical network component industry will grow at 40 percent for the next three years. This growing opportunity has optical component manufacturers in many sectors of the industry elated at demand. At the same time, they are searching for faster, more cost-effective ways to automate the manufacturing process.

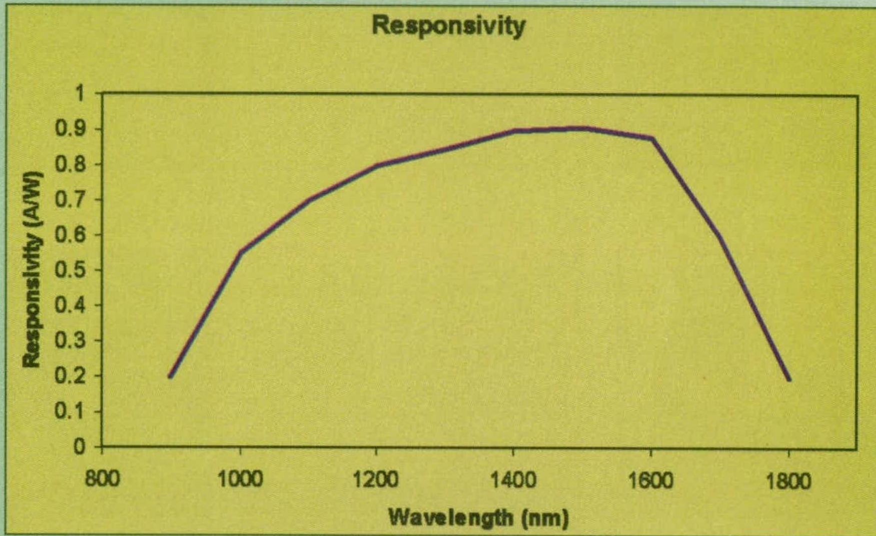

Figure 1. Example of a typical infrared photodetector response curve.

Generally, companies must verify and calibrate optical components for manufacturing, quality assurance, research, production tests, etc. Although the types of tests vary depending on the components being manufactured, optical power measurement is common across all optical devices and procedures.

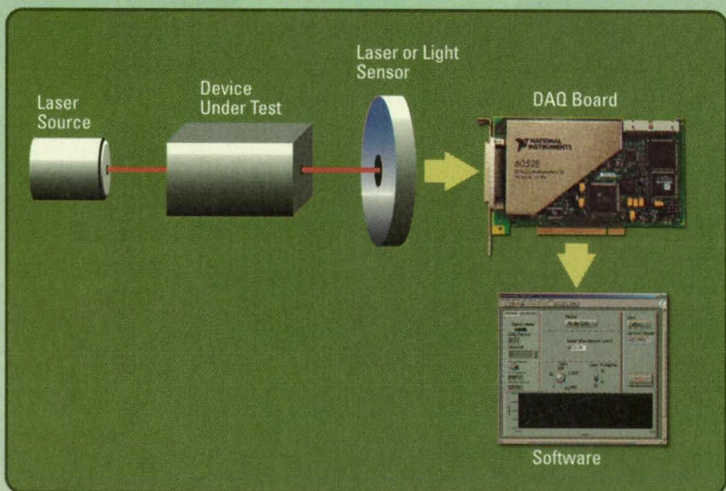

Figure 2. PC-based optical power measurement system using DAQ plug-in modules and LabVIEW.

Optical power measurement is the most common measurement in the optical industry. There are several optical power sensors, which convert light to an electrical signal. The most common sensor uses photodiodes that output current. This low-level current passes through a transimpedance amplifier that applies a gain and converts the signal to voltage. Sensors on the market are tailored to general and specific applications, depending on their specifications, materials, and design. The main factors to consider when selecting a sensor are detectable wavelength (nm), power range (W), measurable area (inches squared), and response (rise) time. If an optical sensor that meets your application criteria cannot be located, you can simply choose from the thousands of base-line detector devices such as photodiodes and phototransistors, and use an appropriate amplifier to create a conditioned signal readable by a plug-in data acquisition (DAQ) board or oscilloscope. Figure 1 shows a typical photodetector response curve.

A DAQ system, or a voltmeter, reads the voltage returned by the sensor and converts it to an optical power response. Figure 2 illustrates a typical computer-based optical power measurement system. Both the voltage reading and the energy response are sensor-dependent and often depend on the wavelength being analyzed. The measures of power are generally expressed in watts (W) or decibel milliwatts (dBm), while tests application values, like insertion loss, are measured in decibels (dB).

Measuring the optical loss or insertion loss of an optical component is also a very common test. In it, the device under test is placed between a light source and an optical power meter. The source emits a signal into the DUT. These sources (examples include tunable lasers from New Focus and continuous-wave lasers from EXFO) are generally specialized devices to output signals

with wavelengths in the optical transport bands. The power meter measures the intensity of the light as it enters and exits the DUT. By measuring the light both before and after the DUT, the amount of power lost inside the DUT is calculated.

The optical power meter, the instrument traditionally used to measure optical power, is a standalone device with one or two input channels. OPMs convert a sensor input to a power response based on the sensor's response table. A computer-based system using a plug-in data acquisition board can perform the same optical power measurements using an optical sensor with lower cost, faster performance, better flexibility, and better system integration. In addition, a 16-bit DAQ board is more than 0.008 percent accurate, three orders of magnitude better than the average sensor.

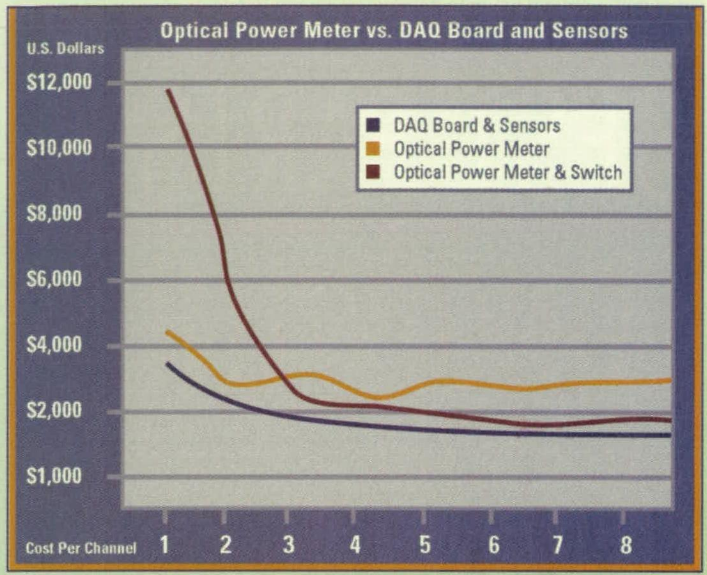

Figure 3. Price comparison of optical power measurement systems using GBIP-based optical instruments and a plug-in DAQ board with optical sensors.

In Figure 3, the price per channel of three systems is compared:

- A stack of four two-channel optical power meters with eight sensors and one GPIB controller boards with four GPIB cables;
- One system with a PC control board, one optical power meter module with one sensor, and one eight-channel optical switch module in a control box; and
- One National Instruments (NI) PCI-6052E high-resolution data acquisition board with eight optical sensors, BNC terminal block, and cable.

The DAQ system is the least expensive of the three configurations. When using all the channels, the DAQ system with eight channels costs $10,000, which is more than $10,000 less expensive than a stack of optical power meters and about $2000 less expensive than the optical switch configuration.

By implementing a DAQ system with an optical sensor, you can measure and test your units in a fraction of the time needed by standalone GPIB instruments or optical switches. Some switches take 180 milliseconds to route a signal. In the same time the PCI-6052E can make 7492 optical measurements, provided you have a fast enough optical sensor. Another benefit of NI hardware is the real-time system integration bus (RTSI). The NI timing bus directly connects DAQ, IMAQ and motion boards for precise synchronization of functions. With RTSI, the boards can use the same clock and triggers. Measurements, movements, and pictures are synchronized every time they are taken.

In addition to providing improved performance, the DAQ system is flexible and easy to update. The DAQ boards reads voltages and converts the voltage readings to power values through software. Therefore it is compatible with a variety of photodetectors from many vendors within the voltage range of operation of the DAQ boards. It requires only the conversion factor to translate the sensor's output to real power values. In addition, you can also use the same DAQ board to measure other signal types such as thermocouples, signal waveforms, circuitry responses, etc.

For example, you can set up the eight channels on the PCI-6052E'to read any combination of these signals. Moreover, it provides two analog output channels to output waveforms or control voltages, eight bidirectional digital lines to turn on/off equipment, and two general-purpose counter/timers to generate TTL pulses or measure time precisely. More importantly, when used in a production environment, these PC-based systems can be adapted and modified as the process model changes.

By using an integrated platform, you can easily use DAQ, motion control, GPIB, serial, and image acquisition components from NI. You can take advantage of programming examples in LabVIEW, Measurement Studio, and TestStand. One example of an application is optical component precision alignment. With a PC-based system, you can obtain up to 40 times faster alignment with a much smaller footprint. You can synchronize optical power measurements, control motion axes, and analyze video inputs to achieve the best hardware performance. Using an integrated platform, you can decrease development time, perform faster measurements, increase throughput, and maintain a smaller support staff.

Optical power measurement systems can be calibrated with plug-in DAQ boards and optical sensors to provide NIST-traceable values. Many plug-in products are shipped with a certificate of conformance and calibration, which provides the documentation to satisfy ISO-9000 requirements and provide traceability to NIST. Calibrated optical sensors have uncertainties that can be used with the calibrated specs of the DAQ boards to calculate the total uncertainty of the system.

Many of NI's multifunction data acquisition devices can be used to make these power measurements. NI delivers accurate measurements, high resolution, long reliability, and minimum noise. For example, the NI-6052E DAQ board is high-channel, high-accuracy (16-bit) and high-speed (333,000 samples per second). The 6052E directly connects with the BNC-2120, providing eight BNC analog input channels. This is an ideal connection for most of these photoreceivers, which connect to BNC cables. NI can also supply cable (SH68-68-EP) and a terminal block (BNC-2120).

Many vendors make light sensors suited for different wavelengths. In the example below, the sensor is New Focus's Model 2001, which performs visible light measurements (400-1060 nm). It has a power range of 1 microwatt to 10 milliwatts, and uses standard coaxial connections. The sensors can also be calibrated using standard DAQ calibration tools in LabVIEW.

LabVIEW is used extensively for research and development, manufacturing, production and test of optical components. NI developed applications free of charge to measure optical power and power loss. The following examples were designed to read one and two sensors, respectively. They can, however, read several sensors with simple modifications.

With LabVIEW, you can drive optical power measurements. LabVIEW is a powerful package that integrates buses

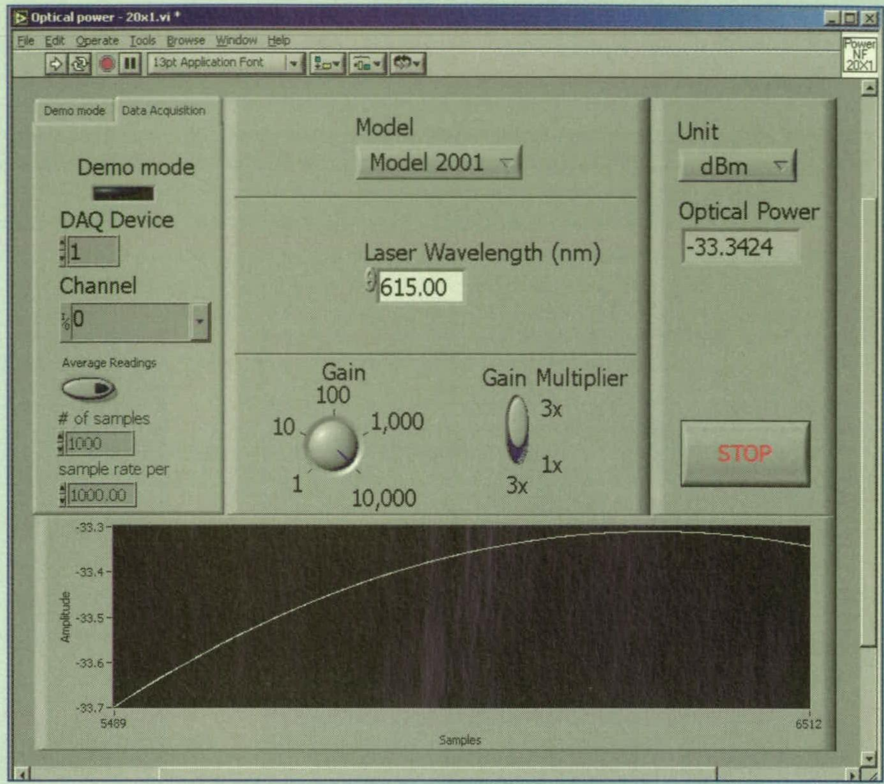

Figure 4. Example of LabVIEW optical power measurement application.

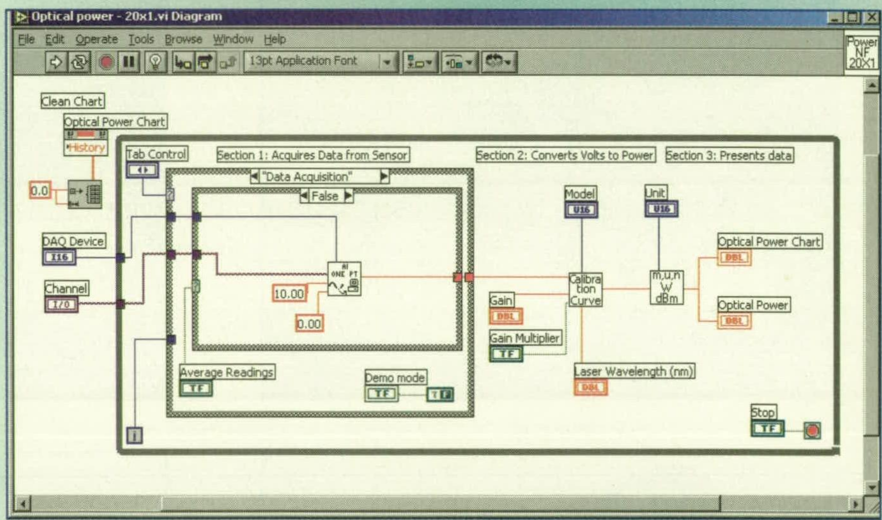

Figure 5. Example of a diagram of an optical power measurement application.

like GPIB and serial RS232/485, and also equips the user with the power of Excel, SQL, and the Internet. LabVIEW has statistical analysis tools, such as average, max/min value, standard deviation, data chart, data trend, curve fitting, data logging to disk, and database.

A sample LabVIEW optical power measurement front panel is shown in Figure 4. This example can be downloaded from http://www.ni.com/telecom/ and Opto Electronics may be selected. The example is divided into three sections: acquiring the sensor data, converting voltage to power, and presenting the results, as in Figure 5.

In section 1, the VI acquires the voltage data from the sensor, using a data acquisition function: AI sample channel.vi. This function reads the data from the sensor. You may also select an option to average the input to improve accuracy. The example can run without a DAQ board or any hardware in "Demo Mode," in which users may select an average voltage and the deviation for the simulated input.

The Calibration Curve VI, in section 2, converts the voltage acquired in section 1 to a power value. The user selects gains, wavelength, and model of the sensor. With the sensor setups, the conver-

sion VI converts the voltage to an optical power value in watts.

Section 3 presents the values read on the optical power display. A selection of units is available (watts, milliwatts, microwatts, nanowatts, picowatts, and dBm). The example also has a historical chart that helps the user to identify trends and compare data.

NI also developed a LabVIEW example for optical power loss. Using this example, you can compare the optical power of two sensors. The example has the same structure as the optical power measurement example, with three section: acquiring the sensor data, converting voltage to power, and presenting the results. The two main differences are in the sections for acquiring data and presenting the results. In the first, two channels of data are measured from two sensors instead of only one in the former. In addition, the results displayed is the difference between the two measurements representing the power loss.

As the demand for optical components continues to grow, optimizing design validation and manufacturing test of these components is crucial. Using open-standard PC-based systems is not only an economical solution, but also a tool that can be used to save manufacturing space, reduce development time, increase manufacturing speed, and enhance hardware integration. Synchronizing production hardware for optical power measurements, motion control, vision and test brings improved performance to the measurement and automation world. In addition, impressive cost savings and performance enhancements are realized.

National Instruments provides hardware and software tools that leverage computer technologies to create high-performance measurement and automation systems. Using advanced plug-in data acquisition boards in combination with high-speed photodetectors and transimpedance amplifiers, fast and accurate optical power measurements can be realized. Large optoelectronics companies saw significant improvements in production cycles of tenfold to fifteen-fold using NI plug-in DAQ boards as well as synchronized motion and vision boards. By leveraging an open-industry standard, such as PXI or CompactPCI, you can build a flexible and scalable solution for optical power measurement, component alignment, and production test.

For further information, please contact Jon Pafk at National Instruments Inc., 11500 N. Mopac Expwy, Austin, TX 78759; (512) 683-6868; fax: (512) 683-5759; E-mail: jon.pafk@ni.com.


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NASA Tech Briefs June 2001, page 33

Fiber-Optic Transducers for Distributed Sensing of Volatiles: An Optical Nose (NPO-21105)

The term "optical nose" refers to a fiber-optic chemical sensor of a type proposed by a team at NASA's Jet Propulsion Laboratory to enable distributed measurement of the concentrations of volatile compounds. Optical noses could enable rapid measurement of gas mixtures (e.g., volatile compounds in air) at multiple sensing locations along their lengths, which could be of the order of kilometers. They would include a commercially available hand-held optical time-domain reflectometer (OTDR) and a fiber-optic transducer. The fiber would be coated with a polymer that swells when it absorbs a volatile compound. The outer surface of the polymer would be coated with a gas-impermeable film. At designated sensing locations along the fiber, the film would be removed in patterns to form half-circumference, millimeter-wide notches through which gases could enter the polymer. The absorption of volatile compounds through a notch would engender shear stress which, in turn, would cause local variation in the fiber's index of refraction. These variations would cause part of the incident laser light to be reflected, and the OTDR would make time-resolved measurements of the intensity of the reflected light.

For further information, access the Technical Support Package (TSP) ***free on-line at*** ***www.ptbmagazine.com*** *under the Physical Sciences category.*

NASA Tech Briefs July 2001, page 46

MQW-Based Blocked Intersubband Detector for Low-Background Operation (NPO-21073)

Researchers at NASA's Jet Propulsion Laboratory are developing multiple-quantum-well (MQW) AlGaAs/GaAs infrared photodetectors for operation under low-background conditions. These devices are expected to function at a temperature of 30 K without nonlinear effects or delayed responses. The MQW-based block intersubband detectors includes a heavily doped MQW emitter section with barriers that are thinner than in prior QWIP devices. This thinning of the barriers results in a large overlap of sublevel wave functions, thereby creating a miniband. Because of sequential resonant quantum-mechanical tunneling of electrons from the negative ohmic contact to and between wells, any space charge is quickly neutralized. At the same time, large tunneling current through the whole device is suppressed by a relatively thick, undoped AlGaAs layer between the MQW emitter section and the positive ohmic contact.

For further information, access the Technical Support Package (TSP) ***free on-line at*** ***www.ptbmagazine.com*** *under the Electronic Components and Systems category.*

NASA Tech Briefs June 2001, page 36

Rare-Earth Optical Temperature Sensors

A fiber-optic temperature sensor recently developed at John H. Glenn Research Center utilizes narrow-band near-infrared radiation emitted by rare-earth ions. These sensors are suitable for use in harsh environments at temperatures above the maximum (1700 degrees C) that PtRh thermocouples can withstand. The maximum operating temperature for these optical temperature sensors can equal or exceed 2002 degrees C. A sensor of this type is an optical fiber, coated at its input (hot) end with a film that contains a rare earth. Infrared radiation emitted at the input end of the optical fiber travels to the output end, then through a band-pass filter with a narrow pass band that lies within the emission wavelength band of the rare earth. The filtered radiation impinges on a photodetector, the output of which is processed to obtain an indication of temperature.

For further information, access the Technical Support Package (TSP) ***free on-line at*** ***www.ptbmagazine.com*** *under the Physical Sciences category.*

Photonic Switching Devices Using Light Bullets

Light bullets would be used to deflect each other.

Ames Research Center, Moffett Field, California

A class of proposed photonic switching devices would utilize interactions among light bullets that have been studied theoretically. Because they function at speeds much greater than those of electrically, magnetically, and acoustically actuated switching devices, these and other photonic switching devices are attracting increasing attention as potential solutions to the problems of switching in the development of advanced communication networks, signal-processing systems, and digital computers.

The concept of a light bullet is a special case of the more general concept of a soliton: A light bullet is a small pulse of light that, in a suitable optically nonlinear material, retains its shape and is guided along its path of propagation by virtue of a balance among diffraction, group-velocity dispersion, and nonlinear self-phase modulation. To be suitable for supporting light bullets, a material should have a negative group-velocity dispersion and a sufficiently large nonlinear index of refraction.

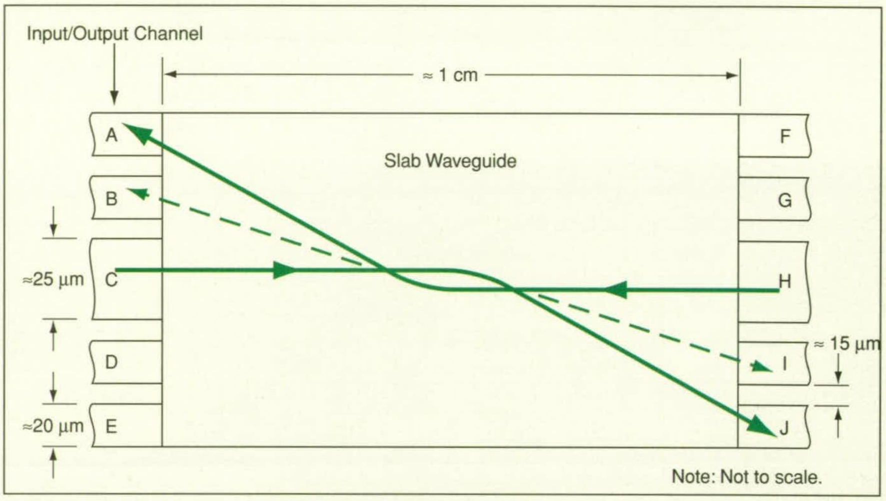
Computational simulations have shown that two counterpropagating light bullets that approach each other within approximately the width of one of them would attract each other enough to change their directions of propagation by appreciable amounts: This phenomenon would be exploited to effect switching in the proposed devices. The figure schematically depicts a typical proposed device comprising a rectangular slab waveguide with multiple input/output channels at both ends. In one example, a light bullet would enter along a horizontal path through a central channel (channel C) simultaneously with another light bullet entering along a slightly laterally displaced horizontal path through the opposing central channel (channel H). Upon passing each other near the middle, the two light bullets would attract each other, causing the upper one to be deflected onto a downward slant and the lower one to be deflected onto an upward slant. The amount of attraction would increase with the intensity of either light bullet and would decrease with increasing lateral separation. Hence, by suitable choice of the intensities and the lateral separation between entry paths, one could cause the light bullets to travel to chosen output channels (A or B for the leftward-propagating light bullet, and I or J for the rightward-propagating bullet). Of course, if no light bullet were to enter through channel H, then the light bullet entering through channel C would propagate without deflection and leave through channel H.

There are many potential variations on the basic theme described above. For example, one light bullet could be made to enter horizontally through channel C and the other light bullet made to enter through channel I at a slant chosen to make the two light bullets pass near each other, deflecting each other to chosen output channels. Yet another variation would be to time the entering light bullets so that they would meet at a location other than the middle, the location being chosen in conjunction with the intensities and the lateral displacement to deflect the light bullets to the desired output channels.

A proposed material for a device like that shown in the figure is a commercial doped glass that has a nonlinear index of refraction of 1.11×10^{-14} cm^2/W and a group-velocity dispersion of −220 ps^2/km for light at a wavelength of ≈3.5 µm. It is estimated that this material would handle light bullets with a duration of ≈100 fs. The light bullets would be ≈10 µm wide in the plane of the figure, with a thickness about equal to that of the waveguide slab (≈2 µm).

The peak power needed to obtain a nonlinear effect strong enough to support a light bullet is an important consideration in designing a practical photonic switching device of this type. The peak power needed in this theoretical example has been estimated to be 150 kW. At a duration of 100 fs, the corresponding energy in a light bullet would be 15 nJ. These power and energy parameters are within the capability of currently available lasers.

However, it may be possible to reduce the power and energy requirements through the choice of a different nonlinear optical material. For example, the estimated required peak pulse power for a suitable semiconductor nonlinear optical material would be about 15 kW. The required power might be reduced even more sharply by use of multiple-quantum-well semiconductor structures: it has been estimated that such a structure might support the propagation of a light bullet at a peak power of only about 0.01 W.



Light Bullets Entering Through Opposing Channels would pass close to each other near the middle, where an attraction between them would deflect them to desired output channels. The dimensions shown here are for the example of doped glass described in the text. The dimensions would scale with the proposed nonlinear material.

This work was done by Peter M. Goorjian of **Ames Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

This invention has been patented by NASA (U.S. Patent Nos. 5,963,683 and 5,651,079). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14057.

Closed-Loop Microsphere Laser for Optoelectronic Oscillator

Feedback control of the frequency of a pump laser is no longer necessary.

NASA's Jet Propulsion Laboratory, Pasadena, California

A prototype ring laser in which a transparent microsphere serves as an electromagnetic-mode selector has been constructed in a continuing effort to develop optoelectronic oscillators for generating light signals amplitude-modulated by microwave signals, all with low phase noise. Optoelectronic oscillators could be used as signal sources in fiber-optic and microwave communication systems and in radar systems.

An optoelectronic oscillator is a hybrid of photonic and electronic components, designed to exploit coupling between optical and electronic oscillations. Optoelectronic oscillators have been described in several previous articles in *NASA Tech Briefs*, the most recent being "Optoelectronic Generation of Optical and Microwave Signals" (NPO-20090), Vol. 22, No. 9 (September 1998), page 50. An optoelectronic oscillator includes, among other things, a laser that operates in multiple modes, plus a high-speed photodetector that samples the laser output. The laser is designed so that the frequency intervals between its modes include the microwave frequency of interest; thus, the microwave frequency of interest appears as one of the beat notes in the photodetector output.

In some previously developed optoelectronic oscillators, long fiber-optic feedback loops were used to obtain low phase noise. Undesirably, a long fiber-optic loop adds considerably to the size and weight of an oscillator; it also makes the frequency intervals between modes so small that selection of the desired modes becomes difficult. In some optoelectronic oscillators developed more recently, fiber-optic loops were replaced with transparent microspheres configured as high-Q (where Q is the resonance quality factor) resonators in conjunction with pump lasers operating under feedback control of frequency (see Figure 1). In a microsphere, propagation in a long fiber is replaced by equivalent orbiting of light by total internal reflection in "whispering-gallery" modes. It has been demonstrated experimentally that in visible light, $Q \approx 10^{10}$ can be achieved in a microsphere, corresponding to a propagation delay of about 3 μs in an optical fiber 0.7 km long.

Feedback control of pump-laser frequency in a microsphere oscillator of the type described above was necessary for locking the pump laser to one of the microsphere modes. The feedback frequency control added complexity and introduced a source of additional frequency and phase noise.

In the prototype ring laser, there is no need for feedback control of laser frequency because the microsphere is an integral part of the laser. The prototype

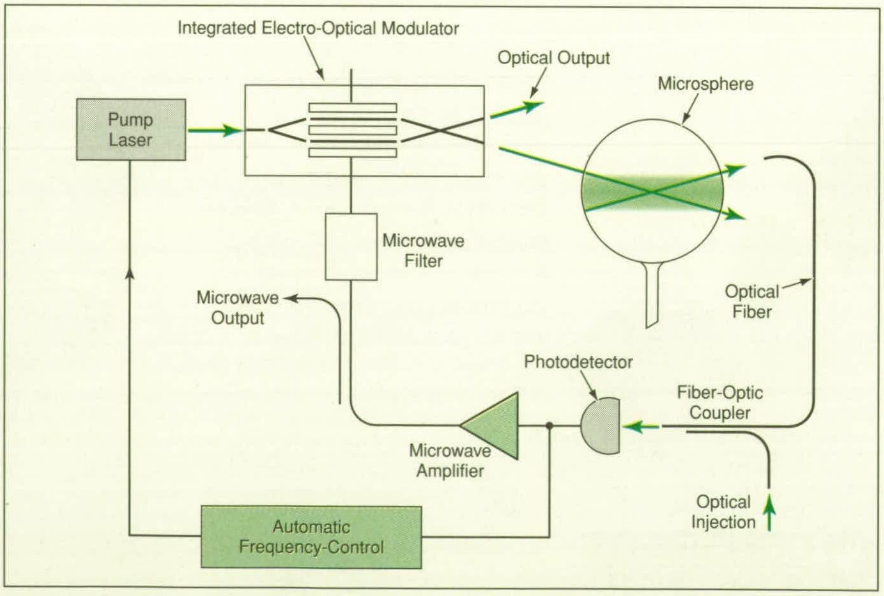


Figure 1. In the **Original Microsphere-Based Optoelectronic Oscillator**, an automatic frequency-control circuit was used to lock a pump laser to one of the electromagnetic modes of the microsphere.

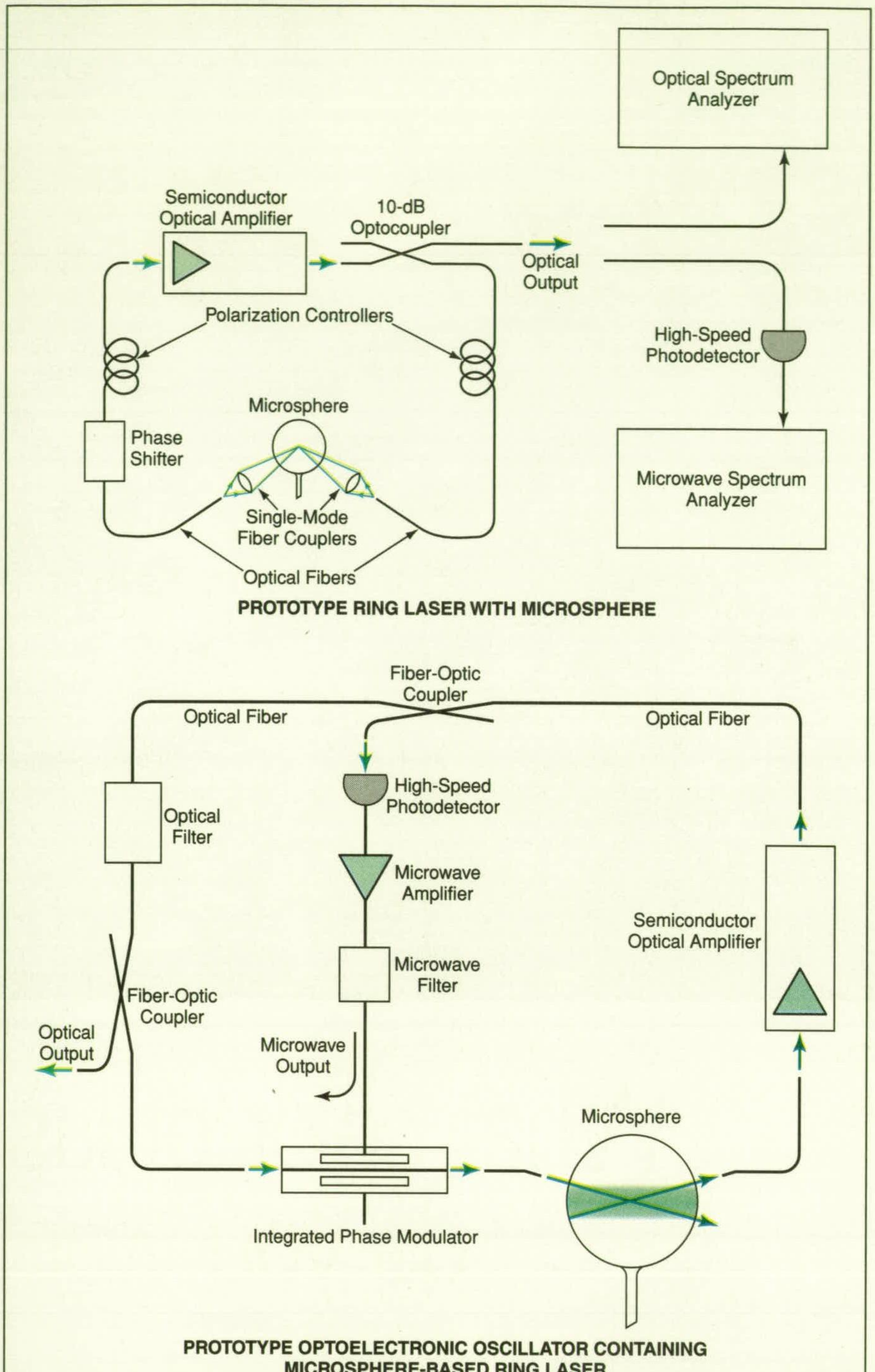


Figure 2. **Microsphere-Based Ring Lasers** have been built to demonstrate direct laser oscillation in microsphere modes, with microwave sidebands at integer multiples of the free spectral range of "whispering-gallery" microsphere modes.

ring laser (shown in the upper part of Figure 2) includes a high-purity silica microsphere and a semiconductor optical amplifier plus ancillary optical components connected in an optical loop. One of the components in the loop is an optocoupler for sampling the laser beam.

In early experiments on the prototype ring laser, the sampled laser beam was analyzed for its optical and microwave-modulation spectral contents. The laser was found to oscillate in multiple whispering-gallery modes of the microsphere. The microwave modulation spectrum included peaks at integer multiples of the whispering-gallery free spectral range of 5.93 GHz. At the time of reporting the information for this article, experiments on the apparatus shown in the lower part of Figure 2 were underway. This apparatus is designed to obtain stable single-frequency operation by introducing (1) optical selection of principal waveguide modes and (2) active microwave feedback as in a standard optoelectronic oscillator.

This work was done by Steve Yao, Vladimir

Iltchenko, and Lute Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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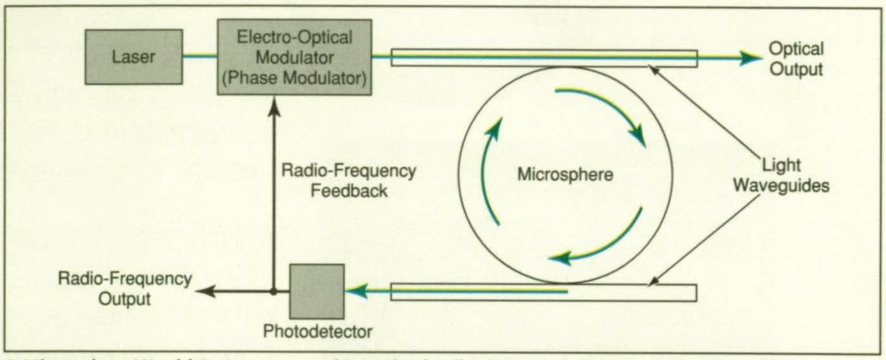
Refer to NPO-20597, volume and number of this NASA Tech Briefs *issue, and the page number.*

Miniature Optoelectronic Oscillators Based on Microspheres

These oscillators could be highly miniaturized.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure depicts an example of a proposed type of optoelectronic oscillator (OEO) based on some of the same principles as those described in the preceding article. In the proposed OEOs as in the OEOs of the preceding article, transparent (e.g., glass) microspheres that exhibit "whispering-gallery" electromagnetic modes at the laser wavelengths of the oscillators would be utilized as high-Q (where Q is the resonance quality factor and is the measure of energy storage time) resonator/delay elements in the oscillator feedback loops.



A **Microsphere Would Be Incorporated** into the feedback loop of an optoelectronic oscillator.

The microspheres, which have submillimeter diameters, would replace the fiber-optic delay lines that have been used in previously developed OEOs. A typical fiber-optic delay line is of the order of 1 km long and is wound on a spool about 3 cm in diameter and 5 cm long. The proposed OEOs could readily be miniaturized because, in the absence of the bulky fiber-optic delay lines, all of their otherwise microscopic optical and electronic components could be integrated on single chips.

In a microsphere, propagation in a long fiber is replaced by equivalent circulation of light by total internal reflection in "whispering-gallery" modes. This light propagates in equatorial planes near the surface. It has been demonstrated experimentally that $Q \approx 10^{10}$ can be achieved in a glass microsphere, limited only by absorption of light in the glass.

In the OEO shown in the figure, the microsphere would be incorporated into the oscillator feedback loop via evanescent-wave coupling with optical waveguides. In one operational scenario, light from the output of a phase modulator would be coupled into the microsphere to excite two modes, corresponding to a carrier signal and a sideband; it would be possible to do this because deviations from perfect sphericity would create modes with a frequency difference falling in the microwave range. The beat note between the two modes would appear at the output of the photodetector and would constitute the desired microwave signal. Some of the beat-note power would be fed back to the modulator to sustain the oscillation.

This work was done by Lute Maleki, Steve Yao, and Vladimir Iltchenko of Caltech for **NASA's Jet Propulsion Laboratory**. *For* *further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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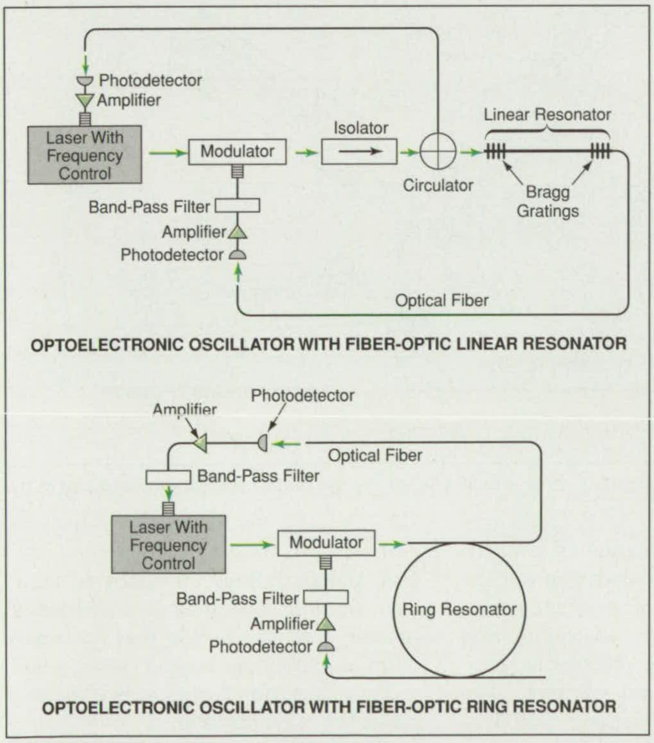
Refer to NPO-20592, volume and number of this NASA Tech Briefs *issue, and the page number.*

Optoelectronic Oscillators Based on Fiber-Optic Resonators

Relatively compact resonators would replace long delay lines.

NASA's Jet Propulsion Laboratory, Pasadena, California

Optoelectronic oscillators (OEOs) of a proposed type would be based partly on the use of fiber-optic linear or ring resonators in place of the long fiber-optic delay lines that have been used to obtain low phase noise in some previously developed OEOs. Although the proposal to use fiber-optic linear or ring resonators was made prior to the use of microsphere resonators described in the two preceding articles, this article appears as the third in the series because the two microsphere-related articles provide information that is prerequisite for



OEOs Could Contain Fiber-Optic Linear or Ring Resonators, instead of long fiber-optic delay lines.

appreciating the technical significance of the proposal.

The two preceding articles discuss two of the disadvantages of long fiber-optic delay lines; excessive weight and size, plus difficulty of selecting desired electromagnetic modes because of smallness of frequency intervals between modes. Two more disadvantages arise in conjunction with the need to prevent temperature-induced frequency drift: (1) it is difficult to stabilize the temperature on a long optical fiber, even when the fiber is coiled on a spool, and (2) optical fibers with low thermal expansion are expensive.

The figure illustrates an OEO with a fiber-optic linear resonator and one with a fiber-optic ring resonator. In the case of the linear resonator, the ends of the resonating length would be defined by Bragg gratings or, alternatively, by highly reflective coatings at the ends of the fiber. In the case of a linear resonator, light would propagate with multiple reflections from the ends; in the case of a ring resonator, light would propagate around the ring many times. Thus, in either case, the effective length of the resonator would be greater than the simple geometric length or circumference.

In either case, the frequency interval between modes would equal the free spectral range of the resonator. In order to obtain oscillation, the frequency of the laser carrier signal must equal that of a resonator mode; the frequencies of the laser-beam modulation sidebands must also equal frequencies of other resonator modes. To provide the necessary alignment of frequencies, the laser frequency must be stabilized at a peak of the resonator transmission spectrum. This can be accomplished by a feedback control subsystem that continually monitors the power of light reflected from the resonator and responds by adjusting the laser frequency to drive the reflected power toward a minimum.

If the resonator could be stabilized, then the absolute frequency of the laser would thus be stabilized. Taking advantage of the relatively small amount of fiber needed to achieve a large effective length, one could then fabricate the resonator from low-thermal-expansion fiber.

This work was done by Steve Yao and Lute Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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Low-Power Shutter Mechanism for a Cryogenic Infrared Camera

The time-averaged power dissipation is <5 mW.

Goddard Space Flight Center, Greenbelt, Maryland

An assembly that includes electromechanical rotary actuators has been developed specifically for use as the shutter mechanism of a cryogenic infrared camera that will be part of an astronomical telescope. The camera will be cooled, by use of superfluid helium, to an operating temperature of 1.4 K. On command, the shutter mechanism rotates a mirror to one of two angular positions, denoted open or closed, at opposite ends of a 38° arc (see Figure 1). When the mirror is in the open position, light gathered by the telescope proceeds unobstructed to the focal plane of the camera; when the mirror is in the closed position, it obstructs the incoming light and provides a dark environment for calibration of the infrared photodetectors in the camera. The shutter mechanism is designed to be rugged, to have relatively low mass (≤1.6 kg), and to satisfy several requirements that pertain to mechanical and electrical performance in the cryogenic environment. A primary requirement is that the power dissipation averaged over time not exceed 5 mW.

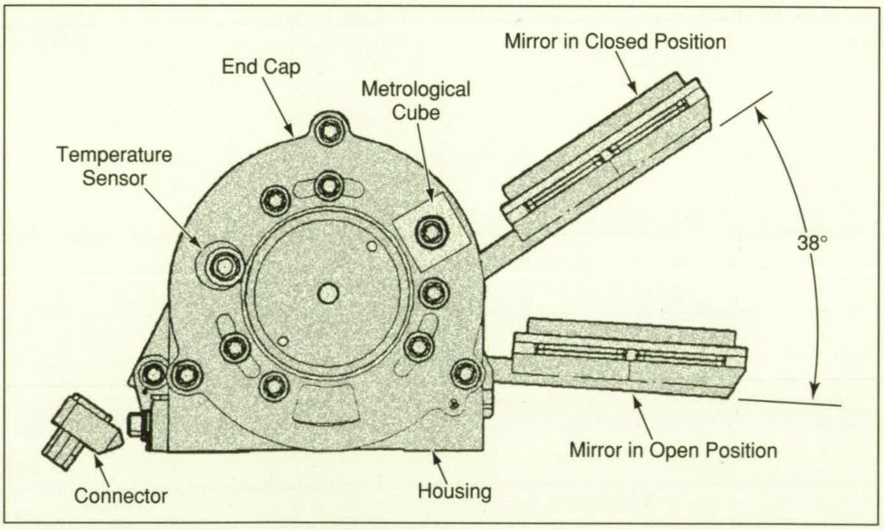


Figure 1. A **Mirror Is Positioned** at either end of a 38° arc by the shutter mechanism described in the text.

Figure 2 depicts the components of the mechanism. The mirror is mounted on an arm that extends radially outward from an aluminum shaft. A tantalum counterweight mounted on the shaft opposite the mirror minimizes the offset of the center of gravity of the shaft, thereby minimizing moments that could be affected by gravitation, acceleration, and vibration. The shaft is supported by bushings that allow free rotation. The bushings fit into holes in end caps. The mating surfaces in the end caps are anodized and impregnated with poly(tetrafluoroethylene) to minimize friction. The shaft is machined to provide a central hollow that accommodates a beryllium copper wire, which serves as a torsion spring to bias the mirror in the open position.

The shaft supports two rotors that are magnetically soft and that are constrained

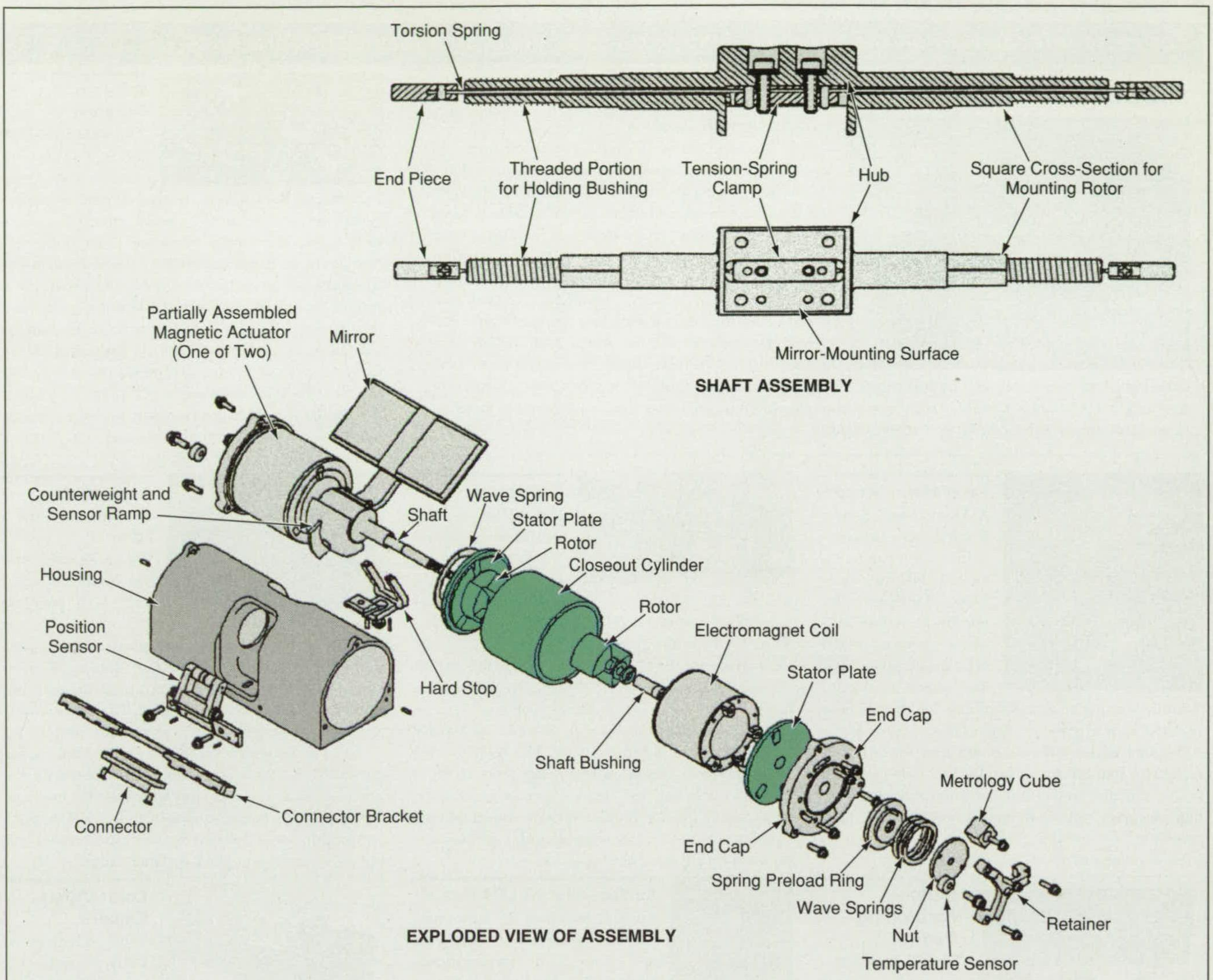


Figure 2. The **Shutter Mechanism** contains two variable-reluctance rotary electromagnetic actuators that oppose a torsion spring that biases the shutter toward the open position.

in fixed angular positions relative to the shaft. These rotors are the moving parts of two variable-reluctance electromagnetic actuators. The stationary parts of each electromagnetic actuator include an electromagnet coil plus two magnetically soft stator plates and a magnetically soft closeout cylinder that completes the magnetic circuit. Electric current in the electromagnet coil of each actuator generates a magnetic field that is focused by the stators and passes through the rotor.

The geometry of the rotor and stators is such that the reluctance of the magnetic circuit varies with the angular position of the shaft, decreasing toward the closed position. As in any such actuator, this arrangement gives rise to a torque in the direction of decreasing reluctance. Hence, the application of current to the electromagnet coil gives rise to a torque that opposes the spring bias, turning the mirror toward the closed position.

A magnetic latch is essential for satisfying the requirement of low average power dissipation. The magnetic latch comprises a set of magnetically soft tabs that are affixed to the stators and extend from the stator faces. These tabs make contact with the rotors in the closed position. This contact effectively completes the magnetic circuit, reducing all airgaps to nearly zero, thereby effecting a large decrease in magnetic reluctance. In the low-reluctance condition, the mechanism can be held in the closed position, fighting the spring-bias restoring torque with a lower current than is needed in the noncontact, higher-reluctance condition. The net result is that whereas a current of ≈55 mA is needed to close the shutter, a current of <1 mA is needed to hold it closed.

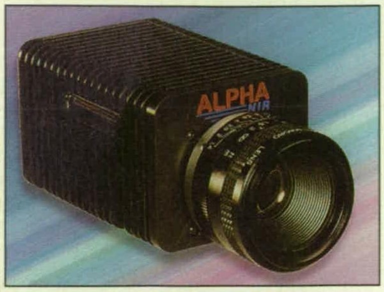
Of course, the naturally low electrical resistance of the electromagnet coil at the low operating temperature also helps to limit the power dissipation. A further reduction in power dissipation is obtained by use of an angular-position sensor and associated control circuitry: Inasmuch as the time taken in closing the shutter is about half a second, the control circuitry initially sends a high pull-in current pulse to the electromagnet, then quickly reduces the magnitude of the current to the holding level. The angular-position sensor informs the control circuitry when the mechanism reaches the closed position, making it possible to minimize the time spent at the higher pull-in current.

This work was done by David Scott Schwinger, Claef Hakun, George Reinhardt, and Clarence S. Johnson of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
GSC-14341

New Products

For more information on the products below, go to www.ptbmagazine.com/products.

PRODUCT OF THE MONTH



InGaAs Near-IR Camera

Indigo Systems, Santa Barbara, CA, introduces the Alpha™ NIR near-infrared camera, employing a 320 × 256 indium gallium arsenide (InGaAs) focal plane array, and sensitive to near- and shortwave-infrared wavebands from 900-1700 nm. The camera is equipped with National Instruments™ PCI-1422 LVDS digital image acquisition boards, digital interface cable, and a LabVIEW™ virtual software instrument. Analysis tools include regions of interest, line profiles, and spot meters. Applications for the Alpha NIR include laser beam profiling, silicon wafer characterization, fiber alignment and inspection, and optical component measurement analysis. With the Alpha NIR software, Indigo Systems believes the user can acquire and display 12-bit digital image data, change sensor head settings, calibrate the sensor head, and analyze data.

Infrared Receiver

The BRM 1010-1020 infrared receiver module from American Bright, Brea, CA, is an infrared remote control system receiver featuring a single-unit-type module with a pin aide and a receiving preamplifier IC. According to American Bright, the series features through-hole leads for wave soldering processes, a remote reception capability of 940 nm at peak wavelength, and reception distances of up to 12 m at ray axis (6 m at 45-degreee cone). Voltage ranges are from 4.5~5.5 for Model 1010 and from 2.7~5.5 for Model 1020. With dimensions of 7.4 mm × 7.98 mm, the device is suited, the company says, for TVs, air conditioners, home computers, and other equipment requiring remote control.

Laser Nano Sensor

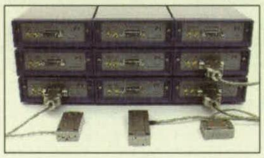
A Laser Nano Sensor from Laser Measurement International, Detroit, MI, uses autofocus principles with resolution as fine as 5 nm at speeds up to 250 kHz, the company says. The sensor is able to quantify surface roughness of any highly reflective material such as glass, precision measurement of silicon wafers, lenses, circuitry, or any mirror-type finishes, and for semiconductor production. Benefits of the sensor include noncontact measurement with very high accuracy and high measurement speed, and small laser spot size that can measure displacement to a few nanometers, according to the company.

Switchless Industrial Camera

JAI America, Laguna Hills, CA, releases the CV-A60 and CV-A50, an RS-232C-controlled small-form-factor A-series product line. Measuring 29 mm × 44 mm × 66 mm with either a 1/2-in. monochrome CCD sensor for the CV-A50 model, or a 1/3-in. monochrome CCD sensor for the CV-A60, the product line has no mechanical switches. The company believes that this increases reliability to as much as 100,000 hours mean time between failures. The RS-232C command protocol allows camera setup from a PC, a "dumb" terminal, or hyper terminal software. Applications for the A-series include semiconductor manufacture, electronics assembly and inspection and preassembly parts inspection.

Audio/Data System on One Fiber

The NTK3655 and the NTK3656 series from NTK NewTek, Princeton, NJ, are frequency-modulated frequency-division-multiplexing (FMFDM) based devices that transmit 4 video channels one way and duplex audio/data or two duplex data channels on one fiber. The series is available in LED-based, 1300-nm multimode versions for up to 4 km. Models NTK 3855 and NTK3856 are single-mode versions that employ 1310-nm lasers for distances of 40 km and comply with RS-250C medium-haul standards. Specifications include 7.5-MHz video bandwidth, >60 dB signal-to-noise ratio, and 17-dB optical budget and optical dynamic range.

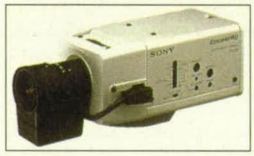


Nano-Positioning Device

The PI NanoAutomation™ stages from Polytec PI, Auburn, MA, are nano-positioning devices providing a positioning and scanning range up to 38 micrometers with submillisecond settling time and small rotational errors in the microrad range, according to the company. The devices are equipped with capacitive feedback sensors that provide subnanometer resolution and stability. The stages are operated with PI's E-750.CP controller, and provide 90-microsecond servo-loop update rate, a fiber-optic interface for communication (>1 Mbit/sec), autocalibration functions, and patented control algorithms.

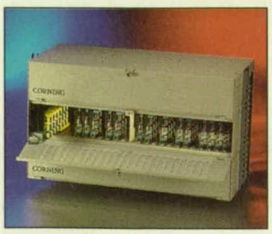
Surface-Mount LED Pixels

Lumex, Palatine, IL, announces its line of point-source red, green, and blue (RGB) surface-mount LED pixels, which are able to generate any mixture of the three primary colors, according to the company. Built-in reflectors and/or lenses combine the output of these chips to create each point-source pixel. High-density full-color displays are created by placing the driver electronics on the rear side of the circuit board and mounting the LED pixels side by side on the front of the board. The LED pixels are available in five different packages: a 2832-size (2.8 × 3.2 mm) rectangular transfer-molded package; a 3632-size (3.6 × 3.2 mm) rectangular printed circuit board carrier package; a 5-mm × 5-mm square dome; a T5-mm round dome; and a T8-mm round dome.



Color Video Camera

Sony Electronics, Park Ridge, NJ, introduces a color video camera containing a half-inch ICCD sensor utilizing Sony's Exwave HAD™ technology to provide f.8 at 2000 lux sensitivity with low smear, the company says. The camera features 768 × 494 effective pixels with a horizontal resolution of 470 TV lines and a 50-dB signal-to-noise ratio. The DXC-190 accepts C and CS lens mounts by using an adjustable ring on the body, eliminating the need for additional adaptive optics. Sony says the camera is designed for high-end surveillance, point-of-view shooting, photo IDs, and industrial microscopy applications like semiconductor wafer inspection.



Splitter System

Corning Cable Systems, Hickory, NC, introduces its high-density xDSL POTS splitter system featuring modular design that allows service providers to add 8 subscribers per line card or 192 subscribers per fully populated shelf. This design allows providers to scale from 8 subscribers in two rack units to 576 subscribers in 7 rack units. The system is certified under NEBS Level 3 standards, and FCC Part 15 and cULus. It is designed for use in central office and remote cabinet environments, Corning says, and is aimed at the North American telephony market.

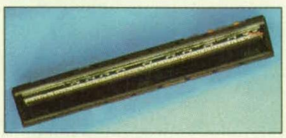
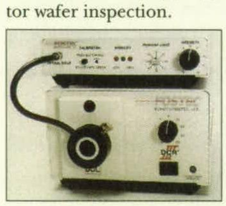


Image Scanner

The P1227MC-A4 from Peripheral Imaging Corp., San Jose, CA, is a contact image sensor module with 4 parallel video outputs, each capable of pixel clocking rates up to 5 MHz. Designed for high-speed scanning applications, the module is capable of outputting up to 15,000 A4 document-size duplex images per hour, capturing both sides of the document simultaneously at a resolution of 8 dots/mm. Twenty-seven integrated monolithic scanning chips, each with 64 photosensing elements, are cascaded to form one contiguous 1728-pixel linear image sensor module. The integrated chips include the photosensors' associated multiplex switches, digital shift register, and chip selection switch.



Light Feedback Module

Schott-Fostec, Auburn, NY, announces the Equalizer™ light feedback module, designed to stabilize light output for machine vision inspection applications. Features include compatibility with all DCR® series halogen light sources, user-defined intensity setting to provide control of the light output and/or lamp life, and a feedback indicator light that signals when it is time to change the lamp. Two configurations of the Equalizer are available. Option one includes a reference Modulamp® unit for use with off-the-shelf fiber optic products. The second option configures the unit to accommodate fiber optic products that are custom-made with an integrated reference bundle.

Venting Closed-Cell Foam Panels

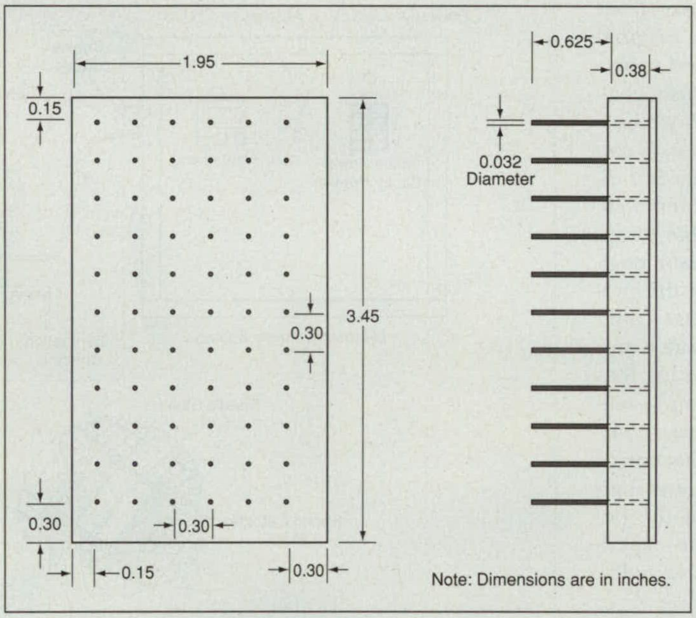
Stresses caused by differential gas pressures are reduced.

Marshall Space Flight Center, Alabama

A technique for reducing in-flight loss of closed-cell foam insulation has been devised. In the original application, foam is used for thermal insulation on the external tank of the space shuttle. As the space shuttle ascends, aerodynamic effects cause an increase in surface temperature of the foam. This heating increases the internal cell gas pressure and reduces cell wall strength. The difference between the increasing pressure of the gases trapped in the foam cells and the decreasing pressure of the ambient air contribute to stresses that can break off pieces of foam during flight. Perforating the foam with small holes makes it possible for some trapped gases to escape, reducing the stresses sufficiently to keep the foam intact during ascent. This technique reduced in-flight foam loss by more than 95 percent. The vent holes could offer similar benefits in other applications where materials are subjected to thermal and pressure gradients.

A tool for making vent holes comprises a regular array (typically, a square pattern) of pins held in a backing plate. The shape of the array and the spacing, length, and diameter of the pins must be optimized for the particular material application, configuration, and environment(s). For the original space-shuttle application, the optimum dimensions were found to be those shown in the figure.

One needs at least two identical tools to ensure the regularity of the holes across a foam panel. To begin making the holes, one carefully places the first tool in the desired initial position with the pins in contact with the surface of the foam, then evenly and gently presses pins into the foam until the tips of the pins make contact with the substrate to which the foam is attached. The second tool is placed adjacent to the first tool, then pressed into the foam in the same way. Then the first tool is withdrawn and repositioned adjacent to (but on a different side of) the second tool, and so forth, until the pattern of holes extends over the desired panel area. The relative positions of the pins within each tool and the adjacency of the two tools ensure the proper positioning of the holes across the area.



This **Tool Is Used To Perforate a Foam Panel** with holes in a square array.

This work was done by Hale Davidson of Lockheed Martin Corp. for **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category.*

MFS-31498

Thermal-Stress Technique for Cutting Thin Glass Sheets

Highly localized heating generates highly localized stresses.

Goddard Space Flight Center, Greenbelt, Maryland

A technique based on the generation of highly localized thermal stresses has been devised as a means of cutting both flat and curved glass sheets of thicknesses between 30 and 600 μm. The technique is reliable, accurate, and economical. The technique can be used, for example, to cut thin glass sheets for microscope slides and for covers on laptop-computer displays and other flat-panel displays.

Heretofore, thin glass sheets have been cut, variously, by use of lasers or by use of diamond tips and knives. Laser cutting is expensive. Diamond tips and knives generate microfractures that make glass sheets more susceptible to breakage along lines other than the intended cut lines. Cutting of thin, curved glass sheets by use of diamond tips and knives is expensive and difficult.

In the present technique, an electrically heated tungsten tip is applied to the glass to be cut. Because of the low thermal conductivity of glass, a large amount of heat can be concentrated in a narrow region surrounding the heated tip. The local concentration of heat gives rise to thermal stresses that can be large enough to break the glass locally and smoothly. As a result, from a macroscopic perspective, the heated tip works like a knife that cuts through the glass.

This work was done by William W. Zhang and Delmar H. Arbogast of **Goddard Space Flight Center**. *For more information, contact the Goddard Commercial Technology Office at (301) 286-5810. Refer to GSC-14364.*

Microwave-Sterilizable Access Port

Materials can be transferred into and out of closed bioreactors without contamination.

Lyndon B. Johnson Space Center, Houston, Texas

The microwave-sterilizable access port is an apparatus that functions in a simple, quick, and reliable manner to reduce significantly the risk of contamination during transfer of materials into or out of bioreactors or other microbially vulnerable closed systems. A major improvement over equipment developed previously for the same purpose, this apparatus can be expected to increase confidence in the microbial integrity of samples taken from closed systems. In tests, the original model of this apparatus exceeded expectations: Although it was rigorously challenged by a variety of microorganisms (e.g., *C. albicans, A. niger, S. faecalis, E. coli, K. terrigena, Ps. cepacia, B. pumilus, B. stearothermophilus*), it performed very well. The apparatus is easily adaptable to applications in cell culture and tissue engineering, and to applications in the production of diverse products that could include foods, drugs, bottled water, soft drinks, and fruit juices. By ensuring that sterilization can be achieved simply, reliably, and quickly, the microwave-sterilizable access port will facilitate collection of samples, delivery of nutrients, and harvesting of products, all without the potential for contamination of the experimental or production systems, samples, or the environment.

The microwave-sterilizable access port comprises two main assemblies: a microwave-power source and an access port (see Figure 1). The access port includes a sterilization chamber, an in-line valve, and a specimen-transfer device. During normal operation, the in-line valve is closed and the bioreactor or other system of interest is isolated. The access port houses a cylindrical aperture into which the specimen-transfer device is inserted. At the bottom of the aperture is a smaller hole for access to the sterilization chamber. In preparation for sterilization and transfer of a specimen, a small amount (≈500 µL) of distilled water is introduced into the sterilization chamber through the smaller hole, taking care not to deposit water within the larger cylindrical cavity. In further preparation for sterilization and transfer of a specimen, a specimen-transfer subassembly that comprises a pre-sterilized septum and the specimen-transfer device is inserted in the sterilization chamber, septum end first.

Positioning of the specimen-transfer device within the access port for insertion, sterilization, and puncture of the septum is controlled by a three-position rotating cam mechanism. Figure 2 shows the mechanism in the open, sterilization, and access positions. Rotation of the three-position cam to the sterilization position during insertion causes establishment of a septum seal, so that the chamber becomes closed to the outside. Once this seal has been established, electrical power is applied to a magnetron in the

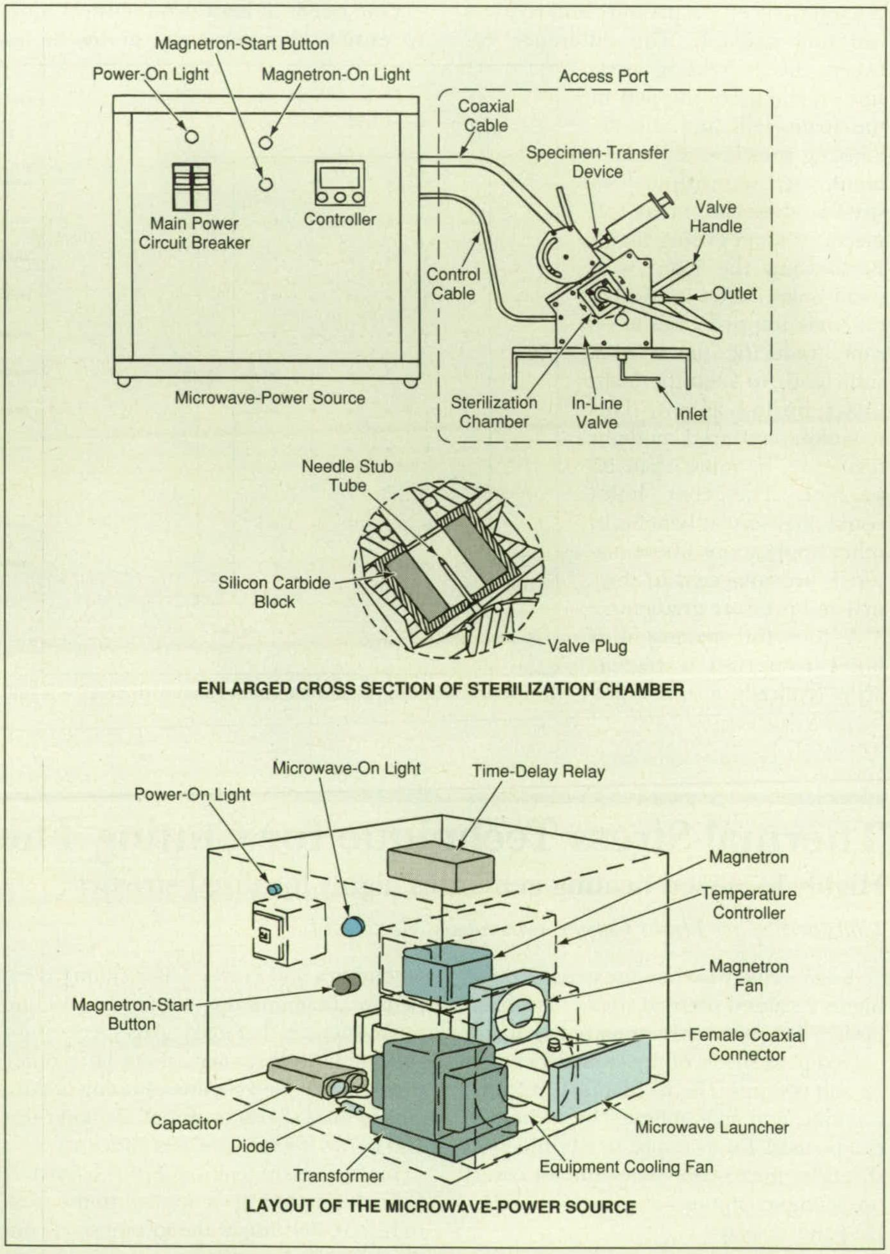


Figure 1. **Microwave Power** heats water to generate steam that sterilizes critical specimen-transfer components inside the sterilization chamber just before a transfer is effected.

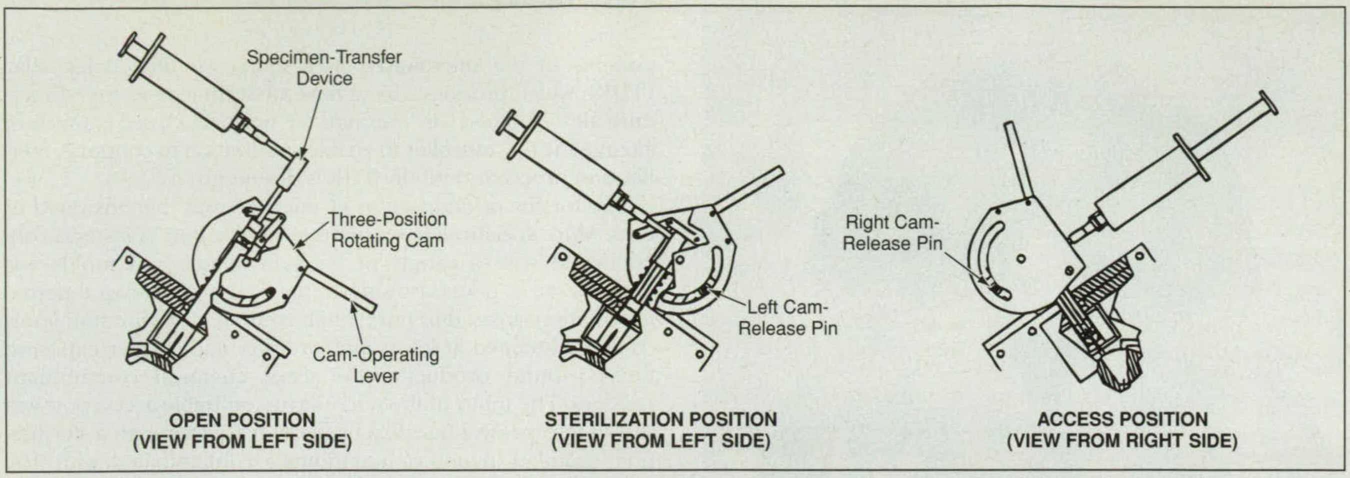


Figure 2. A **Mechanism That Includes a Three-Position Rotating Cam** positions the specimen during the various steps of the sterilization and specimen-transfer operations.

microwave-power source. Microwave power is coupled from the magnetron, via a coaxial cable, into the sterilization chamber, where the microwave power becomes further coupled to a silicon carbide block and with the small amount of water (microwaves can couple strongly with lossy dielectric materials like H_2O and SiC) to produce heat. The heat causes the water to flash to superheated steam, which then pressurizes the chamber and sterilizes all exposed surfaces. The temperature is monitored with a thermocouple mounted in the SiC block.

When the temperature reaches ≈300 °C (≈572 °F) [typically after ≈30 seconds] the microwave power is automatically turned off and a solenoid vent valve opens, releasing a small amount of steam and condensate. The three-position cam is then rotated to the access position. During the rotation, the sterilized septum surface is pierced by a sterile needle stub tube that is part of the specimen-transfer device. Then access to the bioreactor or other closed system can be gained by turning the in-line valve to "access" position; once this has been done, a specimen can then be either collected from, or inserted in, the bioreactor or other system by use of a syringe that mates with the specimen-transfer device via a Luer lock connection. To terminate access to the system, the in-line valve is closed, the three-position cam is returned to the open position, and the specimen-transfer device is removed.

A cabinet houses the magnetron, a microwave-power controller, and other components of the microwave-power source. A time delay relay (TDR), which provides a fixed time safety limit, is set for ≈45 seconds and is latched "on" through the normally closed contacts of a temperature controller to enable sterilization to continue. Sterilization proceeds until the TDR is de-energized

The totality of destruction of microbes was demonstrated in tests. More specifically, wet thermal sterilization of systems contaminated with a variety of bacteria, yeasts, and molds was demonstrated. It was also shown that by use of hydrogen peroxide solutions instead of pure water, equivalent sterilization levels could be attained at lower temperatures and shorter exposure times without producing the usual chemical contaminant residues. The utility of the microwave-sterilizable access port was shown in repetitive transfers of sterile media through a sterilization chamber that was intentionally contaminated with 106 colony-forming units (CFU) of *B. stearothermophilus*, a thermophilic spore-forming bacterium used as the standard microbial challenge for wet-heat and steam-sterilization methodologies. Bidirectional transfer of sterile media was also demonstrated: at the end of the trial, no microbial survivors were recovered in any of 80 replicate experiments.

This work was done by Richard L. Sauer of **Johnson Space Center** *and James E. Atwater, Roger Dahl, Frank Garmon, Ted Lunsfort, William F. Michalek, and Richard R. Wheeler, Jr., of Umpqua Research Co.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22802.

Treatment With Ferrates Eliminates DNA and Proteins

Water and perhaps air can be cleansed of microbiological (probably including viral) contamination.

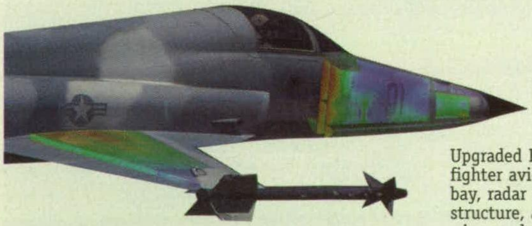
NASA's Jet Propulsion Laboratory, Pasadena, California

Ferrate (VI) salts have been proposed for use in sterilizing water (perhaps also in sterilizing air). The iron in ferrate (VI) salts is in its highest oxidation state (VI), and these salts are extremely strong oxidants. In laboratory experiments, it was shown that treatment of DNA solutions with micromolar concentrations of potassium ferrate (VI) irreversibly inhibits further DNA polymerization and polymerase-chain-reaction (PCR) synthesis. Such treatment does not produce any toxic wastes; instead, what remains after treatment are iron ions, which can be recycled and which, in some applications, are useful as nutrients.

According to the proposal, ferrate (VI) derivatives fixed on various supports and carriers would be used to oxidize waterborne or airborne protein and deoxyribonucleic acid (DNA) molecules. Examples of suitable ferrate (VI) derivatives could include calcium ferrate, and barium ferrate, and inorganic polymers that carry ferrate (VI) ions. Further research is planned in order to develop materials, equipment, and procedures to implement these concepts.

This work was done by Alexandre Tsapin, Kenneth Nealson, and Michael Goldfeld of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP) free on-line at www.nasatech.com under the Bio-Medical category.*

NPO-20881



Books & Reports

All-Pressure Fluid-Drop Model Applied to a Binary Mixture

A report presents a computational study of the subcritical and supercritical behaviors of a drop of heptane surrounded by nitrogen, using the fluid-drop model described in "Model of a Drop of O_2 Surrounded by H_2 at High Pressure" (NPO-20220) and "The Lewis Number Under Supercritical Conditions" (NPO-20256), *NASA Tech Briefs*, Vol. 23, No. 3 (March 1999), pages 66-70. In this model, the differences between subcritical and supercritical behaviors are identified with length scales. The report compares results of the computations with data from microgravity experiments on large drops at temperatures and pressures in the sub- and supercritical regimes.

This work was done by Josette Bellan and Kenneth Harstad of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "An All-Pressure Fluid Drop Model Applied to a Binary Mixture: Heptane in Nitrogen," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20701

Validation of All-Pressure Fluid-Drop Model

A report presents a computational study of the subcritical and supercritical behaviors of a drop of heptane surrounded by nitrogen. The subject matter is basically same as that of the report described in the preceding article, except that the Lewis-number issue is not addressed in detail; however, this article presents the full set of equations which lack in the former. As in the preceding case, the results of the computations are compared with data from microgravity experiments on drops of heptane evaporating in nitrogen at temperatures and pressures in the sub- and supercritical regimes, and conclusions are drawn regarding the accuracy of (1) the mathematical model used in the present study and (2) the limitation on accuracy of a traditional model (known as the d^2 law) at supercritical pressures. The conclusions stated in the report are essentially a subset of the conclusions stated in the report described in the preceding article.

This work was done by Josette Bellan and Kenneth Harstad of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Validation of an All-Pressure Fluid Drop Model: Heptane Fluid Drops in Nitrogen," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20707

Validated Model of a Fluid Drop for All Pressures

The report "A Validated All-Pressure Fluid Drop Model and Lewis Number Effects for a Binary Mixture" presents one in a series of theoretical and computational studies of the subcritical and supercritical behaviors of a drop of fluid and, in particular, a drop of heptane surrounded by nitrogen. The study is based on a fluid-drop model in which, among other things, the differences between subcritical and supercritical behaviors are identified with length scales. It is shown that in the subcritical regime and for a large rate of evaporation from the drop, there exists a mass-fraction "film layer" immediately below the drop surface and the solution of the model equations has a convective-diffusive character. In the supercritical regime, there is no material surface to follow, and this introduces an indeterminacy in the boundary conditions. To resolve the indeterminacy, one must follow an arbitrary boundary, which, in this case, is that of the initial fluid drop. The solution has then a purely diffusive character, and from this solution, one calculates the location of the highest density gradient, which location is identified with the optically observable boundary. It is also shown that the classical calculation of the Lewis number gives qualitatively erroneous results at supercritical conditions, but that an effective Lewis number previously defined gives qualitatively correct estimates of the length scales for heat and mass transfer at all pressures.

This work was done by Josette Bellan and Kenneth Harstad of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20702

Generating Commands for the Mars Polar Lander Robotic Arm

A report discusses the use of the Web Interface for Telescience (WITS) for visualization and command sequence generation in the Mars Polar Lander (MPL) mission. WITS, which has been described in prior articles in *NASA Tech Briefs*, is an Internet-based software system that enables geographically dispersed scientists and engineers to participate in sequence generation for planetary lander and rover missions. Public outreach versions of WITS enable the general public to use WITS to view mission images and plan and simulate their own missions. WITS enables scientists to view mission data and generate command sequences from their home institutions, making it unnecessary for them to travel to a mission control center to participate in the mission. The present report describes how WITS fits in the MPL mission operations architecture and how it was used for Robotic Arm and Robotic Arm Camera sequence generation.

This work was done by Paul Backes and Jeffrey Norris of Caltech and Kam Tso and Gregory Tharp of IA Tech, Inc., for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Sequence Generation System for the Mars Polar Lander Mission," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Intellectual Property group
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20886, volume and number of this NASA Tech Briefs *issue, and the page number.*

The Future of Electronic Device Design

An article discusses anticipated advances in the design of increasingly capable integrated circuits containing ever smaller electronic devices. The article emphasizes the emergence of technology computer-aided design (TCAD) — a discipline in which computer-aided design is combined with computational simulation (based on underlying physics) of the operation and fabrication of devices. The article describes challenges that must be met to expand the role of TCAD as a means of overcoming obstacles to further miniaturization and of shortening integrated-circuit-development cycles. One challenge is to develop better mathematical models of the device physics and fabrication processes to enable the more accurate simulation of what happens as circuit features shrink toward molecular dimensions; meeting this challenge will likely involve development of capabilities for "virtual fabrication," in which all aspects of production processes and devices produced could be computationally simulated. Another challenge is to develop new, generally applicable TCAD software with the flexibility and functionality needed to perform increasingly complex and accurate computations. A third challenge is to obtain the enormous computational power needed for advanced TCAD by setting up an Internet-based distributed-computing grid, which would utilize thousands or even millions of computers while they were idle.

This work was done by Bryan A. Biegel of MRJ Technology Solutions, Inc., for **Ames Research Center**. *To obtain a copy of the article, "The Future of Electronic Device Design," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Systems category.*
ARC-14303

Airlocks for Pressurized Rovers

A report presents a survey of the design engineering and scientific literature on airlocks and on planetary-exploration vehicles ("rovers"), from the perspective of evaluating existing and potential design concepts for airlocks for pressurized rovers. The airlocks are the key to designing a pressurized rover that is useful and productive for the full range of activities and operational requirements. The report presents a representative embodiment of each of these three airlock types through illustrations of a "simplified rover." The report concludes with a cogent set of design recommendations and characteristics for the three types of airlocks that would be particularly relevant to the design of a highly capable pressurized planetary rover.

This work was done by Marc M. Cohen of **Ames Research Center**. *To obtain a copy of the report, "Pressurized Rover Airlocks," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
ARC-14557

Multi-Shock Blankets for Protecting Spacecraft

A report discusses multi-shock blankets, which are under investigation for use in protecting spacecraft against orbiting debris from prior spacecraft missions. Multi-shock blankets are described in comparison with early protective metallic "bumpers" and with a somewhat more recent invention called the "multi-shock shield." A multi-shock blanket is a stand-alone, self-contained shield system that includes several layers of ceramic (or equivalent) shields separated by a flexible foam material.

This work was done by Bruce D. Dvorak of

The Boeing Company for **Johnson Space Center**. *To obtain a copy of the report, "Multi-Shock Blanket" and copies of companion documents "Hypervelocity Impact Shield" (U. S. Patent 5,067,388) and "Multi-Shock Shield Support Study," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)}, to The Boeing Company. Inquiries concerning licenses for its commercial development should be addressed to

The Boeing Company
ATTN: Bruce Dvorak
5301 Bolsa Avenue
M/C H020-F603
Huntington Beach, CA 92647

Refer to MSC-22989, volume and number of this NASA Tech Briefs *issue, and the page number.*

Subgrid Analysis of Mixing Layer With Evaporating Droplets

This report presents an analysis of a database from computational simulations of a droplet-laden mixing layer (i.e., evaporating droplets of a liquid fuel in air) undergoing a transition to turbulence. The basic governing equations were those of transport of discrete droplets through a flowing gas; the droplets were followed in a Lagrangian frame whereas the gas was followed in an Eulerian frame. The analysis involved the extraction of subgrid scale (SGS) models from flow fields generated using the direct numerical simulation (DNS) approach, in which the governing equations are solved directly at all relevant length scales.

This work was done by Josette Bellan and Nora Okong'o of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Priori Subgrid Analysis of Temporal Mixing Layers with Evaporating Droplets," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20791

Spacecraft-Facility Microbes Tolerate H_2O_2, NaCl, and Heat

A report describes experiments that were performed to isolate and characterize microbes that survive conditions of controlled circulation of air, desiccation, low nutrient concentrations, and moderately high temperatures in a spacecraft-assembly facility. These conditions are more severe than those to which the natural strains of the same microbial species are ordinarily exposed. This study is part of continuing research on related issues of (1) efficacy of sterilization (e.g., by use of H_2O_2 and/or heat) of spacecraft to be used in planetary exploration, (2) the use of selected microbes as indicators of the effectiveness of sterilization, and (3) the feasibility of commercial utilization of enzymes produced by microbes that tolerate severe conditions.

This work was done by Kasthuri Venkateswaran of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Isolation and Characterization of Hydrogen Peroxide Resistant, Thermotolerant, and Halotolerant Microbes from a Spacecraft Assembly Facility," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Bio-Medical category.*
NPO-20980

Study of High-Performance Polyimide Foams

This report describes an experimental study of thermal-stability, mechanical, and flammability properties of foams of several different densities made of three different polyimides. The study was performed because (1) prior such studies were performed on polyimide films rather than foams and (2) the synthesis of polyimide foams is a relatively recent development. There is a need to determine the suitability of each foam for potential applications — for example, as flame retarders, thermal and acoustic insulators, gaskets, seals, vibration-damping pads, spacers in adhesives and sealants, extenders, and flow and leveling aids.

This work was done by Erik S. Weiser and Terry L. St. Clair of **Langley Research Center**, *Martha K. Williams of Kennedy Space Center, and Gordon L. Nelson and James R. Brenner of Florida Institute of Technology. To obtain a copy of the report, "High-Performance Polyimide Foams," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

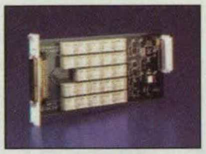
This invention has been patented by NASA (U.S. Patent Nos. 6,133,330 and 6,180,746). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Gregory S. Manuel at (757) 864-2556 org.s.manuel@larc.nasa.gov. Refer to LAR-15977/15767.

New on the MARKET

CAD Software for Pocket PCs

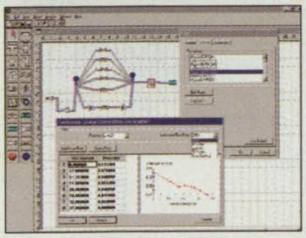
Arc Second, Dulles, VA, has released PocketCAD PRO 4.0 CAD software for Windows® powered mobile devices including Pocket PCs. Powered with AutoDesk® technology, the software allows mobile users to create, view, and edit design drawings at job sites. The software reads and writes DWG™ and DXF™ files, and is compatible with nearly all desktop CAD software packages. EditTrak™ is a merge technology that makes it possible for PocketCAD to replay and merge field changes into the desktop drawing file. The software also includes the PocketCAD PowerPak™, three add-ins comprised of corner, array, and saved view commands. **For Free Info Circle No. 707 or Enter No. 707 at www.nasatech.com/rs**

Plug-in Switch Card



The 1260-116 high-density plug-in switch card from Racal Instruments, Irvine, CA, is a customizable switching platform capable of simultaneously switching power, stimulus, and response signals. The card is a 24-channel, Form C, single-pole, double-throw switch card for switching and control of external devices. The card's plug-in design enables switch card expansion and replacement. The 5A capacity can control external devices such as motors or loads and may be used in high-current switching of AC and DC power supplies or current sources. **For Free Info Circle No. 708 or Enter No. 708 at www.nasatech.com/rs**

Flow Network Modeling



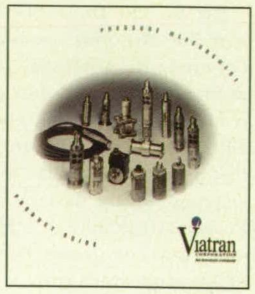
MacroFlow thermal design software from Innovative Research, Plymouth, MN, is an integrated modeling, processing, and data visualization tool for predicting flow and temperature distributions in electronics system packaging design. Features include a graphical user interface to construct flow networks representing the system layout, and a built-in engineering library of common electronic packaging components. A solver to calculate flow, pressure, and temperature at every point in the electronics system package, and an integrated post-processing data and visualization suite for examination of results and their communication, also are included. **For Free Info Circle No. 709 or Enter No. 709 at www.nasatech.com/rs**

Datalogging System

The OM-3000 Series portable datalogger from OMEGA Engineering, Stamford, CT, has an integral backlit LCD display with graphics capabilities that can be used for on-the-spot measurements for all channels. Input ranges, user-defined session names, and sampling intervals are programmed via the built-in keypad. The standard 128K memory allows approximately 100,000 individual samples with date/time stamp to be stored for downloading. Main menu setup selections include channel setup, measure without recording setup, new recording setup, review data set, download data set, memory management, date and time setup, and battery capacity check. **For Free Info Circle No. 711 or Enter No. 711 at www.nasatech.com/rs**

New LITERATURE

Pressure Measurement Tools

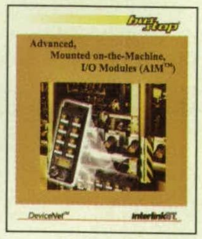


Viatran Corp., Grand Island, NY, offers a brochure describing pressure measurement products for machine control equipment, industrial test facilities, and chemical, food, and pharmaceutical processing systems. Features include gage, absolute, vacuum and differential formats for pressure ranges from 5"WC to 100,000 psi with output types of mV/V, V, mA, and HART. **For Free Info Circle No. 715 or Enter No. 715 at www.nasatech.com/rs**

Panels and Keypads

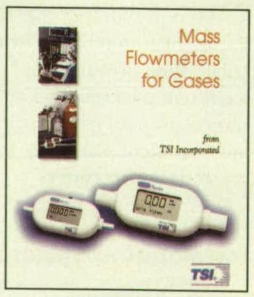
Measurement Specialties, Hampton, VA, offers a 28-page catalog detailing Duralith™ membrane switches, panels, and keypad assemblies. Included are schematic drawings, dimensions, and electrical and mechanical applications of membrane switches, silicone rubber keypads, plastic key assemblies, and injection-molded keyswitches. **For Free Info Circle No. 716 or Enter No. 716 at www.nasatech.com/rs**

Bus Products



A 26-page catalog of bus products for sensors and actuators is available from InterlinkBT™, Minneapolis, MN. The catalog specifies bus requirements including supply voltage, input circuits, output circuits, I/O LED indicators, connections, adjustments, DeviceNet Identity Attributes, I/O date mapping, and produced data size. **For Free Info Circle No. 717 or Enter No. 717 at www.nasatech.com/rs**

Mass Flowmeters



A brochure from TSI, St. Paul, MN, profiles thermal flowmeters for medical, industrial hygiene, metrology, aerosol science, and fuel cell industries. Features include built-in temperature and pressure compensation, 4-millisecond flow response, ±2% of reading, low pressure drop, high turndown ratio, analog output of flowrate, and digital output of flowrate. **For Free Info Circle No. 718 or Enter No. 718 at www.nasatech.com/rs**

Data Acquisition Recorder

Astro-Med, West Warwick, RI, has released a 12-page brochure describing its Dash 18® "One Touch" data acquisition recorder equipped with a 15.4" color display for intuitive touch screen control, and real-time viewing and analysis of waveforms. The instrument features an internal 9-GB hard drive and 18 channels of universal inputs for voltage, thermocouple, and bridge measurements. **For Free Info Circle No. 719 or Enter No. 719 at www.nasatech.com/rs**

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R ❑ Research Lab
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Z ❑ Other *(specify):* ___________

3 Your engineering responsibility is: *(check one)*

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E ❑ Other
(specify) ___________

4 Your job functions are: *(please check all that apply)*

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14 ❑ Engineering Management
16 ❑ General & Corporate Management
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Write in the number of your principal job function ___________

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04 ❑ Software
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06 ❑ Materials
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18 ❑ Sensors/transducers/detectors
16 ❑ Data acquisition
19 ❑ Test & measurement instruments
34 ❑ Power supplies & batteries
35 ❑ PCs & laptops
06 ❑ Workstations
36 ❑ EDA/CAE software
37 ❑ CAD/CAM software
17 ❑ Imaging/video/cameras
38 ❑ Lasers & laser systems
39 ❑ Optics/optical components
40 ❑ Fiber optics
41 ❑ Optical design software
20 ❑ Motion control/positioning equipment
30 ❑ Fluid power and fluid handling devices
31 ❑ Power transmission/motors & drives
42 ❑ Rapid prototyping and tooling
13 ❑ Metals
28 ❑ Plastics & ceramics
27 ❑ Composites
43 ❑ Coatings
80 ❑ None of the above

6 How many engineers and scientists work at this address? *(check one)*

A ❑ 1
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C ❑ 6-19
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J ❑ over 1000

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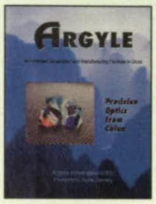

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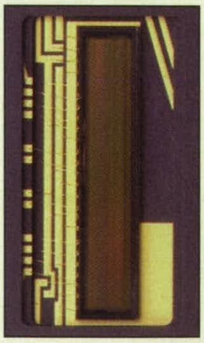

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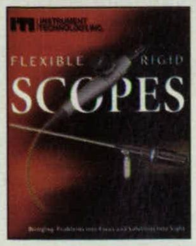

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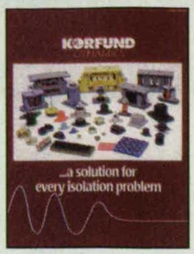

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DATA ACQUISITION AND INSTRUMENTATION eCATALOG

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Dispensing System Used for Space Module Repair

MIXPAC System 400
ConProTec
Salem, NH
603-893-2727
www.mixpacusa.com

Researchers at NASA's Marshall Space Flight Center in Huntsville, AL, have teamed with ConProTec to develop a comprehensive kit for external repairs to NASA space modules. KERMIt (Kit for External Repair of Module Impacts) will seal punctures in the International Space Station caused by collisions with meteoroids and space debris.

The MIXPAC System 400 is a handheld tool used to inject adhesives when making external patches. MIXPAC dispensing systems consist of a dispenser, a dual-barrel cartridge, and a plastic static mixer that all work as an integrated unit. The dual-cartridge containers, which store the resin and catalyst separately to prevent cross contamination, are vacuum filled to prevent air from being trapped inside.

In order to prepare the dispenser for use outside the space station or module, an insulating blanket was added to allow the system to function in the cold temperatures of space. Additionally, since crewmembers using the dispensers will be suited up in bulky Extra Vehicular Activity (EVA) suits, the handle has been altered to make gripping the device easier.

Thiokol Propulsion — the manufacturer of NASA's shuttle solid rocket motors — is using the MIXPAC system to dispense epoxy adhesives in the nozzle bond process.

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Launch Vehicles Use Fiber Optic Leak Detection

Fiber optic hydrogen leak detection system
Intelligent Optical Systems
Torrance, CA
310-530-7130
www.intopsys.com

Intelligent Optical Systems (IOS) has developed for NASA's Stennis Space Center in Mississippi a fiber optic hydrogen leak detection system for space launch systems.

IOS focused on creating a system that would provide real-time hydrogen detection inside and outside of a launch vehicle. The solution was a multi-point fiber optic sensor system consisting of a low-cost light source, standard telecommunications-grade optical fiber, and optrodes with temperature-sensitive indicators.

The use of optoelectronic sensors — which require no power at the sensing point — eliminates the possibility of damaged wiring causing a spark. The optical sensors are also immune to electromagnetic interference and can function in a variety of media.

IOS has received nearly $1 million in funding to develop "a safe, efficient system for detecting potentially catastrophic leaks from cyrogenic tanks and tubing containing liquid hydrogen," according to Reuben Sandler, president and CEO of IOS. "We are very appreciative of NASA's support to move ahead with further engineering of the system," he added.

The fiber optic hydrogen leak detection system in a static test firing on a Delta IV orbital rocket at Stennis Space Center.

IOS and the Boeing Co. successfully demonstrated the system during a static fire test on a Delta IV orbital rocket at Stennis.

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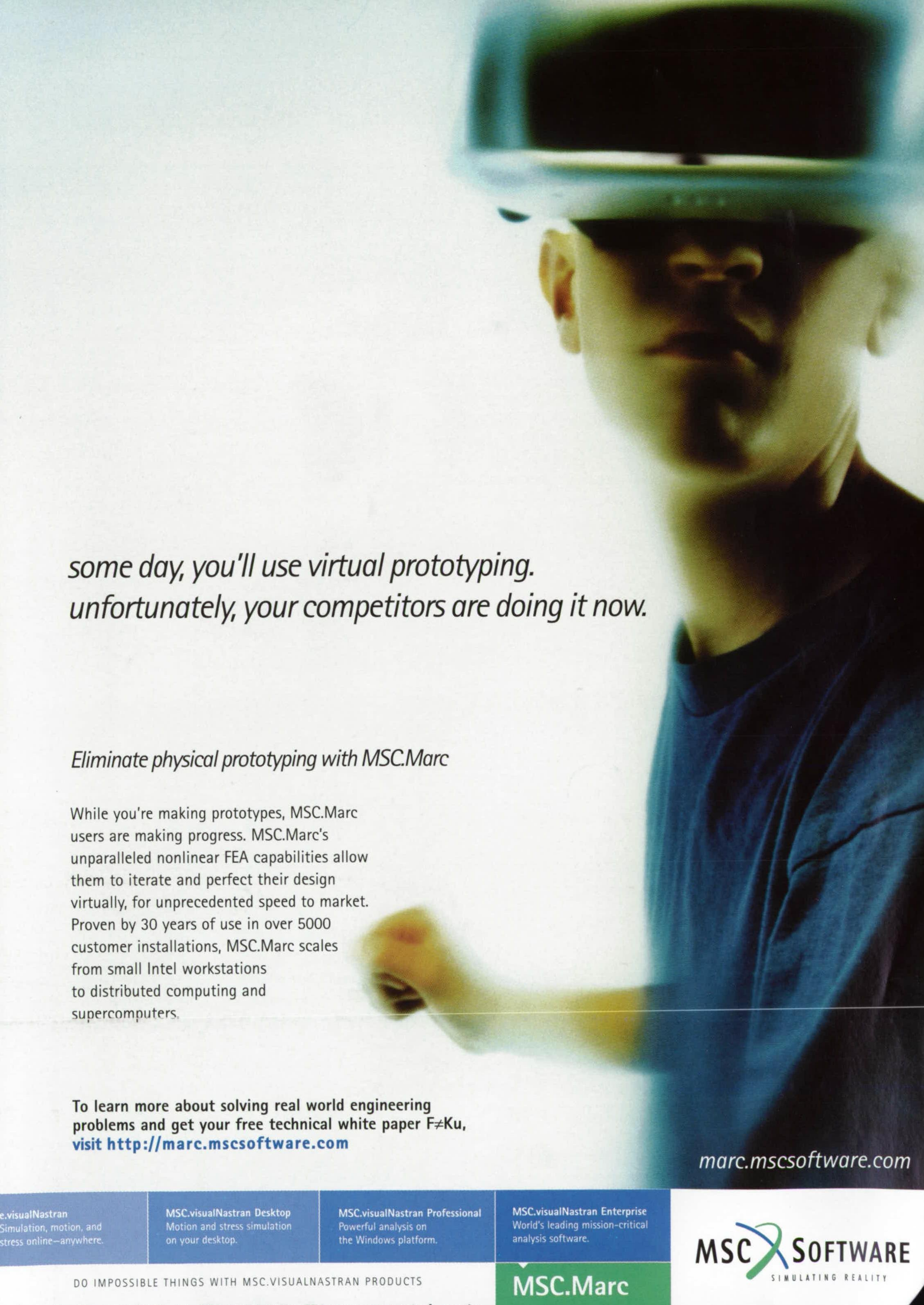
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